2005
MERIT REVIEW & PEER EVALUATION REPORT

HEAVY VEHICLE MATERIALS PROGRAM

Less dependence on foreign oil, and eventual transition to an emissions-free, petroleum-free vehicle

FreedomCAR and Vehicle Technologies Program

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

FreedomCAR & Fuel Partnership

21st CENTURY TRUCK PARTNERSHIP

Department of Energy
Washington, DC 20585

November 2005

Dear Colleague:

This document summarizes the comments provided by the Review Panel for the FY 2005 Department of Energy (DOE) Heavy Vehicle Materials Program Merit Review and Peer Evaluation Meeting, held September 13-15, 2005 at Oak Ridge National Laboratory in Oak Ridge, Tennessee. The goal of this document is to provide the reader with a summary of the comments and scores from expert reviewers from industry and government on these Materials Technologies projects.

The format used in this report is similar to that used in the long-running Advanced Combustion and Emission Control Merit Review and Peer Evaluation for DOE National Laboratory Projects. Information is provided both on a quantitative basis (through project review scores) and a qualitative basis (through reviewer text comments) to outline reviewer opinions on these activities.

Thank you for participating in the FY 2005 DOE Heavy Vehicle Materials Technologies Program Merit Review Meeting. Please feel free to provide suggestions for improving this meeting in the future.

Rogelio Sullivan, Team Leader
Materials Technologies
FreedomCAR and Vehicle Technologies Program

cc: Ed Wall
Connie Bezanson
Tien Duong
James Eberhardt
John Fairbanks
Steve Goguen
Roland Gravel
Phyllis Yoshida
Ken Howden
Gurpreet Singh

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Introduction

This report is a summary and analysis of comments from the FY 2005 DOE Heavy Vehicle Materials Program review, held September 13-15, 2005 at Oak Ridge National Laboratory. The work evaluated in this document supports the work of the FreedomCAR and 21st Century Truck Partnerships. The results of this merit review and peer evaluation are major inputs used by DOE in making funding decisions for the upcoming fiscal year. The objectives of this meeting were to:

- Review and evaluate FY 2005 accomplishments and FY 2006 plans for DOE research in heavy vehicle materials R&D.
- Provide an opportunity for industry participants (engine manufacturers, emission control manufacturers, vehicle manufacturers, etc.) to provide their inputs to the DOE-sponsored R&D program so that the highest priority technical barriers are addressed. The meeting also serves to facilitate technology transfer.
- Foster interactions among the national laboratories and others conducting the R&D.

The Review Panel members, listed in Table 1, attended the meeting and provided written comments on the projects presented. They are peer experts from a variety of related backgrounds including automobile and truck companies, engine manufacturers, emission control system manufacturers, fuels manufacturers, universities, and other U.S. Government agencies. A complete list of the meeting participants is presented as an appendix. A poster session was also held as part of the review, but these projects were not formally scored as part of the review.

Table 1: Review Panel Members

Member Name	Affiliation
YC Chen	Cummins Inc.
James deVries	Ford Motor Company
Ray Fessler	BIZTECH
John Grassi	Caterpillar Inc.
Craig Haberger	Caterpillar Inc.
Robert Hathaway	Oshkosh Truck Corporation
Mark Horstmeyer	Mississippi State University
Stefan Jansson	Volvo Trucks North America
Jack Martens	DAF Trucks
Eric David McCarty	DaimierChrysler Corporation
Harold Pangilinan	U.S. Army TACOM
James Quinn	General Motors Corporation
Peter Schihl	U.S. Army TACOM
VK Sharma	International Truck and Engine Corporation
Jean-Louis Staudenmann	National Institute of Standards and Technology
Nirmal Tolani	International Truck and Engine Corporation
Don Trettin	PACCAR Inc.
Tom Yonushonis	Cummins Inc.

Analysis Method

As shown in Table 1, a total of eighteen industry and government members participated in the merit review. A total of 33 project presentations were given at the meeting, and a total of 196 review sheets were received from the review panel members (not every panel member reviewed every project). To determine the scores for these projects, the projects were placed into two categories that were established in consultation with DOE program managers. These two categories were:

- High Strength Weight Reduction Materials, and
- Heavy Vehicle Propulsion Materials.

Review panel members were asked to provide numeric scores (on a scale of one to four, with four being the highest) for five aspects of the research on their review form, a sample of which can be found as an appendix to this report. The five aspects were:

- Relevance to overall DOE objectives;
- Approach to performing the research and development;
- Technical accomplishments and progress toward achieving the project and DOE goals;
- Technology transfer and collaborations with industries, universities, and other laboratories; and
- Approach to and relevance of proposed future research.

The numeric scores given to each project by the reviewers were averaged to provide the overall score for that project for each of the five criteria. An average score for the five criteria was also calculated within each of the two project categories for all projects in that category. In this manner, a project's overall score can be compared to other projects in that category.

Reviewers were also asked to provide qualitative comments on the five research aspects, as well as on the specific strengths and weaknesses of the project and any recommendations for additions or deletions to the work scope. These comments, along with the quantitative scores, were placed into a database for easy retrieval and analysis. These comments are summarized in the following sections, with an indication of how many reviewers provided written comments for that project and that question. All reviewers of a given project provided a numeric score for each of the five criteria, but did not necessarily provide qualitative comments.

Organization of the Report

This report is organized in two main sections, one section for each of the two main R&D categories. The first page of each section presents a summary of the average scores for the projects in that category, highlighting the highest scores for each of the five scoring aspects and the category average for those aspects. A brief description of the general type of research being performed in each category is also presented.

The remaining pages of each section present the results of the analysis for each of the projects discussed at the merit review. Graphs showing how the particular project compared with other projects in its category are presented, as well as a discussion of these results. A summary of the qualitative comments is also provided.

As a major component of the U.S. Department of Energy's (DOE's) Office of FreedomCAR and Vehicle Technologies (OFCVT), the High-Strength Weight Reduction (HSWR) Materials Technology Development Area seeks to reduce parasitic energy losses due to the weight of heavy vehicles without reducing vehicle functionality, durability, reliability, or safety, and to do so cost-effectively. The development area is focused on the development of materials and materials processing technologies that can contribute to weight reduction. In addition, it is recognized that improved materials may enable implementation of other technologies that can further improve the fuel efficiency of the vehicles.

Below is a summary of average scores for 2005 for the nineteen projects in this category, along with the average, minimum, and maximum score for all projects in this report. The highest score in this category for each question is highlighted. Scores were on a basis of 1 to 4, with 4 being the highest.

Summary of Scores for Projects in this Section

Page Number for Project Summary	Research Project Title	Q1 Relevance Score	Q2 Approach Score	Q3 Technical Accomplish-ments Score	Q4 Tech Transfer Score	Q5 Future Research Score	Overall Average Score
5	*Advanced Composite Support Structures;* Jay Batten (National Composites Center)	3.33	3.17	3.00	2.50	3.17	3.03
7	*Advanced Materials for Friction Brakes;* Peter Blau (Oak Ridge National Laboratory)	2.60	2.60	2.40	3.00	2.20	2.56
10	*Advanced Superplastic Forming Development for HV Structures;* Curt Lavender (Pacific Northwest National Laboratory)	3.33	3.17	3.00	3.00	3.17	3.13
13	*Application of Carbon Fiber for Large Structural Components;* Kevin Simmons (Pacific Northwest National Laboratory)	2.75	3.50	3.00	3.25	2.75	3.05
15	*Application of Superplastically Formed Aluminum for Truck Body Panels;* Nirmal Tolani (International Truck and Engine Corporation)	3.29	3.29	2.57	2.86	3.43	3.09
17	*Applications of Advanced Composites in Heavy Vehicles;* Cliff Eberle (Oak Ridge National Laboratory), Curt Lavender (Pacific Northwest National Laboratory)	3.22	3.11	3.22	3.00	2.25	2.96
20	*Attachment Techniques for Heavy Truck Composite Chassis Members;* Lynn Klett (Oak Ridge National Laboratory)	2.75	3.75	3.00	3.00	3.00	3.10
22	*Basic Studies of Ultrasonic Welding for Advanced Transportation Systems;* Zhili Feng (Oak Ridge National Laboratory)	3.00	2.67	3.17	2.67	3.17	2.93
24	*Counter Gravity and Pressure Assisted Lost Foam Magnesium Casting;* Qingyou Han (Oak Ridge National Laboratory)	3.14	3.00	2.86	3.43	2.43	2.97
27	*Development of Magnesium Powertrain Components;* Mark Smith (Pacific Northwest National Laboratory)	3.33	2.83	2.00	3.00	2.83	2.80
29	*Development of Technologies for the Application of Magnesium Metal Matrix Composites for Heavy Vehicles;* Adam Loukus (GS Engineering)	2.71	2.71	2.57	2.71	2.57	2.66

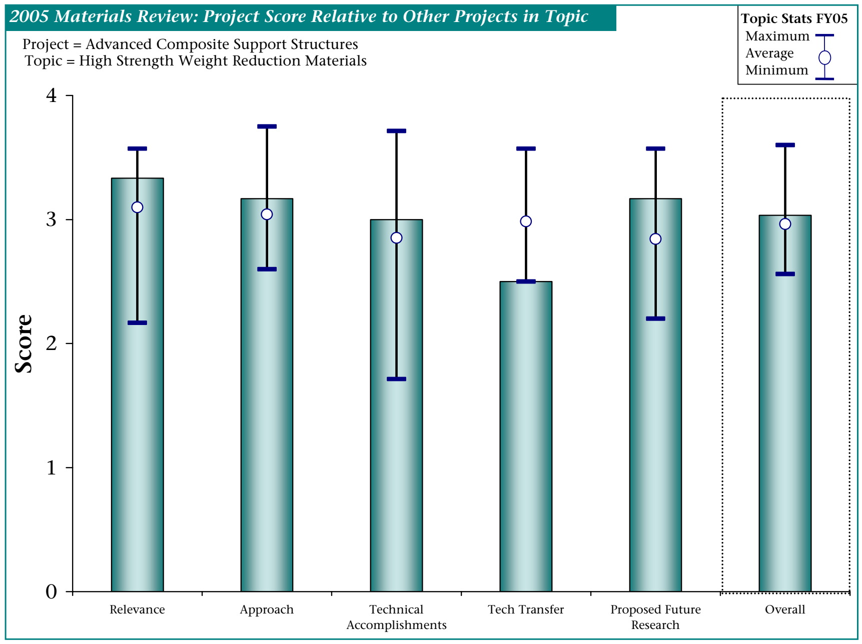
Page Number for Project Summary	Research Project Title	Q1 Relevance Score	Q2 Approach Score	Q3 Technical Accomplish-ments Score	Q4 Tech Transfer Score	Q5 Future Research Score	Overall Average Score
31	*Friction Stir Welding and Processing of Advanced Materials;* Mike Santella (Oak Ridge National Laboratory), Glenn Grant (Pacific Northwest National Laboratory)	3.00	2.89	3.11	3.00	3.11	3.02
34	*Friction Stir-Joined Aluminum Sheet Materials for HV Cab Structures;* Glenn Grant (Pacific Northwest National Laboratory)	3.57	3.75	3.71	3.57	3.57	3.60
36	*Integrated Approach for Development of Energy-Efficient Steel Components;* Leo Chuzhoy (Caterpillar Inc.)	2.17	3.00	2.67	3.17	2.20	2.64
38	*Lightweight Stainless Steel Bus: Manufacturing, Cost, Crashworthiness;* Bruce Emmons (Autokinetics)	3.29	3.00	3.00	2.57	2.57	2.89
42	*Lightweight Trailer-Liburndas Project;* Ben Ubamadu and Kevin Tumlin (Heil Trailer International)	3.50	3.50	3.17	3.00	2.83	3.20
44	*Rapid, Low-Cost Tooling Development;* Cliff Eberle (Oak Ridge National Laboratory)	2.71	2.71	1.71	3.43	2.29	2.57
46	*Thermomechanical Processing of Ti and Ti-6-Al-4V Sheet and Plate;* Craig Blue (Oak Ridge National Laboratory)	3.11	3.00	3.11	3.22	3.44	3.18
49	*Wrought Magnesium Alloy/Process Development;* Joe Horton (Oak Ridge National Laboratory)	3.38	2.75	2.75	2.63	2.38	2.78
	Average Score for This Category	**3.10**	**3.04**	**2.85**	**2.98**	**2.84**	**2.96**

Overall Program Scores

	Q1 Relevance Score	Q2 Approach Score	Q3 Technical Accomplish-ments Score	Q4 Tech Transfer Score	Q5 Future Research Score	Overall Average
Overall Program Average	3.05	3.04	2.88	2.93	2.79	2.94
Overall Program Maximum	3.57	3.75	3.75	3.57	3.57	3.60
Overall Program Minimum	2.17	2.50	1.71	2.00	2.00	2.35

High Strength Weight Reduction Materials

Advanced Composite Support Structures; Jay Batten of the National Composites Center



Brief Summary of Project

This project's goal is to develop economical and durable polymer composite support members (frame crossmembers and the like) for Class 7/8 trucks to achieve 50% component mass reduction. The team has analyzed several component designs and has fabricated a carbon fiber-reinforced prototype support member.

Question 1: Relevance to overall DOE Objectives (Written responses from 3 of 6 reviewers)

One reviewer noted that the project is focused on weight reduction while meeting the OEM objectives, such as cost. Others felt that the potential for weight savings is very high (~35lbs.) if continued through to the ladder system.

Question 2: Approach to performing the research and development (Written responses from 5 of 6 reviewers)

One reviewer noted the researchers have demonstrated a good technical approach and have used lessons learned from past projects, and added that there was good use of modeling. Another person commented that GENOA seemed to be a good software package that can predict fatigue life of the composites. One person noted that their rating reflected the fact that everything can be made better, but it may require more funds. One reviewer felt that it would be difficult to improve the approach given the restrictions put on the project by the partners. They added that making such a large departure from a conventional frame would require a completely fresh look at the design and assembly process rather then replacing components in an existing design. The final reviewer commented that some justification of manufacturing process is necessary. The program is centered on an unstated process and validation that this process is the best is required.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 4 of 6 reviewers)

Several reviewers had positive comments, stating that the researchers are well on track to succeed, while another noted that the progress is significant within the scope of the components being redesigned. One reviewer stated that the project must successfully advance to the ladder assembly for highest impact. The last reviewer noted there are issues on the price of the carbon fiber composite so glass fiber was used, and also noted the issue with the fastening.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 5 of 6 reviewers)

Two reviewers noted that the researchers worked with two OEMs, frame manufacturers and lower-tier partners. One reviewer felt that it is too early in the program to determine success of industry transfer. Others commented that the problem is in the price of the (super)light materials, while another felt that it would seem that there would be other places to reduce weight than in the cross members or frame rails.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 3 of 6 reviewers)

One reviewer simply stated that the project is good. Another commented that the most impact of the project is in the total system approach rather than in individual components; future plans for the ladder structure satisfy this approach. Another reviewer noted that the future work is valuable in that the software applications can be used in other areas, but added that it would seem that more mass can be removed at lower cost and risk in other areas.

Specific Strengths and Weaknesses (Written responses from 6 of 6 reviewers)

- Specific Strengths
  - Excellent match between model and test results.
  - Sound engineering application with aggressive stretch goals.
  - Well thought of project.
  - Good software application development and process development.
  - Development of CAE software for predicting performance of composites.
  - Excellent use of software tools and finite element analysis.
- Specific Weaknesses
  - This is an engineering application, manufacturing processes are mature. Some investigation of new and advanced techniques may be necessary.
  - Will the price of the (super)light materials be the impediment of such good prospective results?
  - To make significant improvements would require a complete frame rather than just replacing cross members. If the entire frame is redesigned repair processes would need to be considered.
  - Need more focus on manufacturing technology for robust mass production of assemblies.
  - What is the life cycle cost of these fiber composite programs? What is the calculated fuel savings for these projects at the reduced weight savings level?

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 4 of 6 reviewers)

- Continue funding through the full system (ladder structure).
- Should also be quantified as realistically as possible in terms of fuel savings. Specific program to make (super)light materials significantly cheaper than what they are today.
- Try to find a partner that is willing to look at a completely new method of building a truck, such as a stressed skin, stiff frame with a more effective suspension.
- Validate process capability, reliability, performance, customer acceptance, and cost-effectiveness of crossmembers before embarking on the next potential application.

Question and Answer Session at Review

Q: Is the 35 pound mass savings cited with glass or carbon reinforcement?
A: With glass.

Q: If the $4.75 threshold for carbon fiber cost is achieved, how much impact will this have in reducing vehicle weight?
A: This would probably allow the use of twice as much carbon fiber leading to a weight reduction of up to 50 pounds.

Q: James deVries - Is this using light flex technology?
A: Continuously oriented fiber technology is being used.

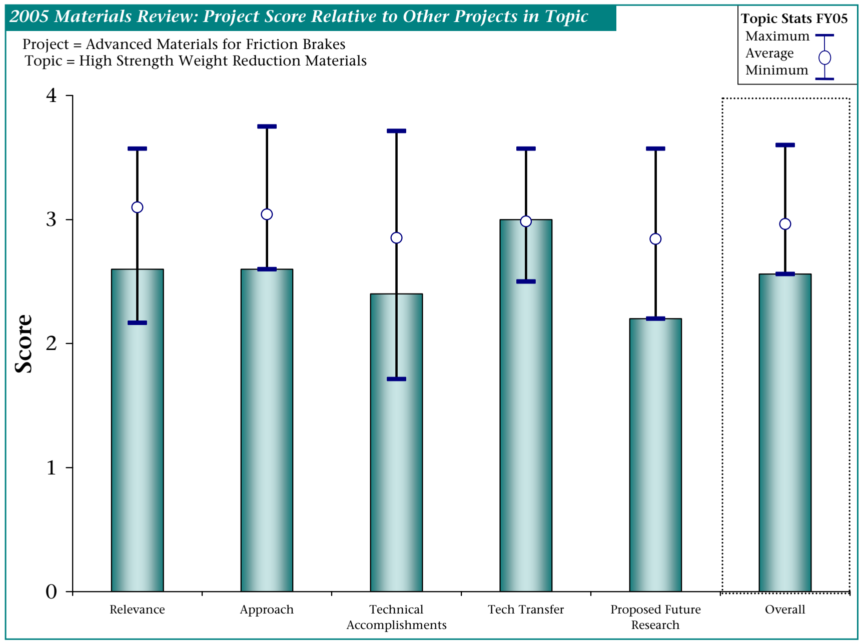
Q: Dr. James Eberhardt - Are the fatigue tests being conducted in real world temperatures and chemical environments? What are the effects of temperature variation and environmental exposure to roadway de-icing materials?
A: We have not tested in these environments yet, but will be doing so during component testing.

Q: Is the GENOA software commercially available?
A: Yes, the Alpha STAR Corporation (creator of GENOA) offers it for sale. They are teaming with other partners in the software industry.

Q: Rogelio Sullivan – Do your backup slides address the joining and structural integrity issues?
A: Lynn Klett will address these issues later in her presentation (Attachment Techniques for Heavy Truck Composite Chassis Members).

High Strength Weight Reduction Materials

Advanced Materials for Friction Brakes; Peter Blau of Oak Ridge National Laboratory



Brief Summary of Project

The stated objective of this project is to identify, test, and analyze the friction and wear characteristics of advanced materials and surface treatments that enable weight reduction in truck brake components while equaling or bettering their performance. The team has examined a number of advanced materials for friction brakes and has downselected to advanced titanium-based composites and thermally-sprayed titanium alloy discs for further testing.

Question 1: Relevance to overall DOE Objectives (Written responses from 5 of 5 reviewers)

One reviewer felt that this was a good application. Another person commented that the aim of the project is not only in line with the DOE mission but also with that of DOT. They added that they hope the collaboration between DOE and DOT already exists on this subject, otherwise it should be encouraged and/or established: the collaboration is likely to produce more benefits than the sum of two independent programs. Others were more critical. One person noted that the project focused on safety with only minor improvements in weight/energy savings. Another felt that an energy retrieval braking systems would be much more in line with the goals of the program. The final reviewer commented that it is difficult to determine how this project will lead to improved fuel economy. They added that it seems that this is a second order effect, and is very long term research compared to the issues facing the industry.

Question 2: Approach to performing the research and development (Written responses from 4 of 5 reviewers)

One reviewer felt that this project represents excellent technical work and an excellent approach. Others were more critical. One reviewer stated that the project needs a parallel effort to understand the critical parameters; i.e., relationship between material characteristics to customer's functional requirements. Another commented that the material selection should be based on a model of the braking process to identify the material characteristics to look for or to develop. The final reviewer was struck by the absence of metrics and also of meaningful comparisons between the materials used in brakes.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 3 of 5 reviewers)

One reviewer felt that the researchers have shown excellent progress and technical work, however, there is not much tie into DOE technical barriers. Another agreed stating that it seems that the project made some progress but in the absence of metrics, it is difficult not only to judge the progress made but also to estimate the progress. The last reviewer stated that the work on the titanium metal matrix composite showed an interesting behavior with respect to the increase in friction coefficient with higher temperature.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 5 of 5 reviewers)

One reviewer noted that the group is working closely with a brake manufacturer. Another noted the close interaction with the supply chain and prototypes in an early phase available to future end users. Others had more questions. One person noted that coordination exists between key partners, but the team needs to identify a clearer commercialization strategy. Another person understood that the existing collaboration seems not to matter in the pursuit of the operations. The final reviewer felt that there was limited industry sponsorship, and that most of the applications seem to be in the racing industry, not the HD trucking industry.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 2 of 5 reviewers)

One reviewer felt that the weight reduction will be reached, but that better performance remains questionable. Another person commented that it seems that everything in this project is toward demonstrating that titanium is the material to consider, regardless of comparison with the outside world. They added that they are not convinced of that: brakes are too important to be limited by work on weight reduction.

Specific Strengths and Weaknesses (Written responses from 5 of 5 reviewers)

- Specific Strengths
  - Friction and wear expertise and correlation to critical parameters. Partnerships with materials and component suppliers.
  - Integrating behavior of brake pad material and disc material. [This] is necessary to take the "black magic" out of the brake pad industry.
  - Very important subject that should be managed as an integration between several federal agencies.
  - Excellent technical work.
  - Systematic approach to test candidate materials.
- Specific Weaknesses
  - End goal was not readily evident; i.e., what is the target date for commercialization?
  - Start with an experimental approach. The impression is that the optimum is not found.
  - Absence of metrics, such as wear rates, braking efficiencies per reference mass; comparisons between braking schemes, absence of any reverse engineering methodology.
  - Difficult to determine how this will help improve fuel economy, emissions etc.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 3 of 5 reviewers)

- Establish commercialization path, along with cost targets/reduction opportunities.
- The current material used for heavy truck disc brakes in Europe is gray cast iron. The gray cast iron is not a standard material but a specially developed grade. This leads to high heat conductivity and resistance to heat cracks.
- The following is not necessarily by order of importance:
  - Program should be strengthened and better structured.
  - DOE and DOT should be involved; brakes are too important to be left with either one; collaboration is more likely to yield the best integration of the best ideas related to brakes.
  - Brakes are necessary for safety of people around the vehicle, in it, and finally for the vehicle itself. Also, since we are talking of heavy vehicles, the effect of heavy braking on pavement should also be considered, especially during the summer.
  - Reverse engineering is necessary to find out what is the best brake system, regardless of its weight. This should be comprehensive and include most of the known makers.
  - This work should contain detailed comparisons between materials, modes of braking within a set of today's metrics and another of desired (better) metrics.

Question and Answer Session at Review

Q: Rogelio Sullivan – Disc brakes are popular in Europe for heavy trucks. What materials are being used? Are they using more conventional materials?

A: Peter Blau –Our project is actually looking at some European materials. More disc brakes are being used in Europe, and DOT regulations will likely force more disc brake usage from the current situation with predominantly (90%) drum brakes. Europe is still in the early stages of developing advanced materials for disk brakes for heavy vehicles as well. The Europeans are doing some aluminum metal matrix composite material testing now. There is no published research on using titanium as a brake material, but are not sure of the true situation since much of the material work is being kept confidential.

Q: Paul Becker – ORNL may want to investigate the availability of a modeling characterization on multi-component frictional materials from Bendix that they had done in the past. This knowledge may still be available at Bendix.

A: Peter Blau – Several papers have been published on our experiment design. It should be kept in mind that there are significant variations in processing: some brake linings aren't cured until they are exposed to in-use temperatures on the vehicle. There are over 200 additives available on the market for brake linings, and there are variations in heat treatment, processing, etc.

Q: Is ORNL looking at alternative materials like aluminum metal-matrix composites in its upcoming investigations?

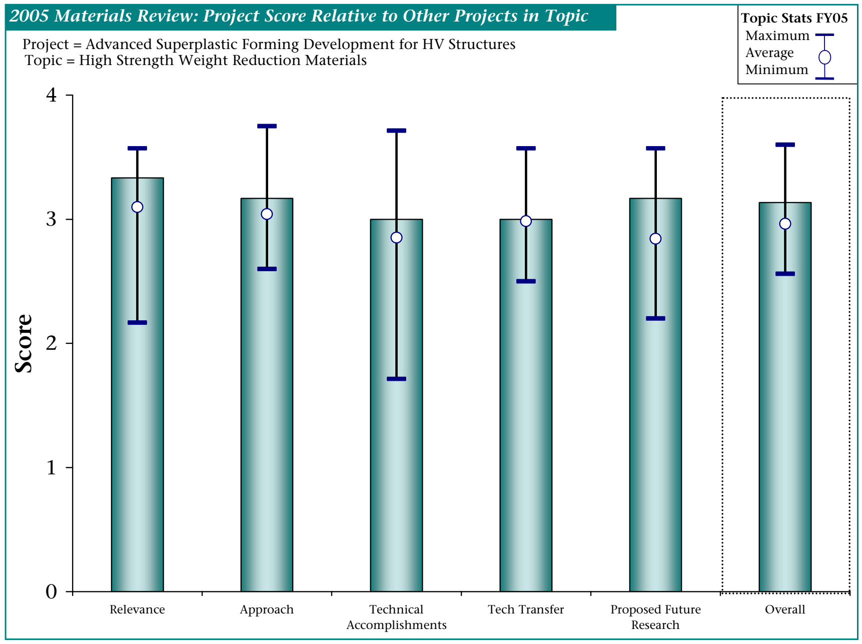
A: Peter Blau – ORNL has already down selected to titanium and ceramic materials. PNNL is conducting the metal matrix composite work for the DOE programs. Aluminum metal-matrix composites are more susceptible to corrosion and have a lower melting temperature; however it may be niche application in some front brake systems.

Q: Is there a correlation between wear characteristics of brakes, their friction characteristics, and their braking efficiency?

A: Peter Blau – We have seen for most materials that high friction-grip generally leads to higher wear rates.

High Strength Weight Reduction Materials

Advanced Superplastic Forming Development for Large Structural Components; Curt Lavender of Pacific Northwest National Laboratory



Brief Summary of Project

This team is working on developing cost and design allowable tools to advance superplastic formed materials and processing capabilities for heavy vehicle applications, and developing superplastic forming process knowledge by producing lightweight demonstration components. The focus areas during 2005 were to provide an OEM with mechanical properties for use in design analysis, to identify low cost tooling methods and to identify challenges for high strength superplastically formed alloy use.

Question 1: Relevance to overall DOE Objectives (Written responses from 4 of 6 reviewers)

One reviewer felt that this is a good project that is well in line with DOE's mission, but they would have rated it higher if laser forming would have been included. Another simply stated the project's goals include saving weight and energy. Another commented that the project includes work towards lighter weight components plus potential for aerodynamics. The final reviewer noted that the concept and technical feasibility have been established.

Question 2: Approach to performing the research and development (Written responses from 5 of 6 reviewers)

One reviewer simply stated that the project seems sound. Another agreed that the project is well in line with DOE's mission, but would have been rated higher if laser forming would have been included. Another felt that the project has done a good job of addressing the technical barriers and obtaining SPF properties of one alloy. One reviewer suggested that a design of experiments studies to organize a parametric study might be useful to identify the important cause-effect relations. The final reviewer cautioned that the project does not address lubricant, cycle time, and material handling, all of which are major commercial factors.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 2 of 6 reviewers)

One reviewer commented that this appears to be a new project as little accomplishments have been shown to date. Although it was stated that uniaxial tests were performed and applied to a multiaxial stress state, little else was done.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 5 of 6 reviewers)

Two reviewers commented that this is a good project, one stating that it is not quite a "4" in terms of score. Another commented that the project appears to have done a good job of involving national laboratory, university, and OEM participation with milestones that include technology transfer. One reviewer noted the interaction with OEMs, suppliers, and universities, and also the development of standards. The final reviewer felt that although significance to the OEM was discussed, particular details with industrial partners were lacking.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 4 of 6 reviewers)

One reviewer commented that the project appears ready to focus on demonstrating the feasibility for specific components, especially if increased properties are needed and alternate alloys need to be considered. Another reviewer felt that the path forward to an economically viable process or product isn't obvious. The final reviewer questioned what the plan is to analyze fatigue of superplastic materials, since fatigue requirements are more substantial than for autos.

Specific Strengths and Weaknesses (Written responses from 4 of 6 reviewers)

- Specific Strengths
  - The project has done a good job of addressing the barriers to implementation of SPF.
  - Well focused program; enabling; good team; scope a bit restricted.
- Specific Weaknesses
  - Lack of structure-property relations have been quantified and also applying uniaxial data for multiaxial stress states could be a problem.
  - The project has focused on one alloy and has not identified specific components for application.
  - Since SMC components can be molded to complex shapes, I don't think it's reasonable to claim improved aerodynamic styling ability; granted, you can make designs more aerodynamic than with conventional aluminum, but not necessarily better than compared to SMC or steel.
  - Not enough metrics to truly measure progress.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 4 of 6 reviewers)

- Quantifying the grain size and grain growth effects during the deformation is warranted.
- Identify a potential application, determine necessary material properties and determine a likely alloy that could achieve the properties with SPF.
- Address production cycle times, lubes, etc.
- The program should go to completion as is. I do not think that there is time, nor additional funds, to include laser forming.

Question and Answer Session at Review

Q: Mark Horstmeyer – Were uniaxial data for 5083 alloys were used to develop the model used to assess the stress-strain measurements of superplastic formed materials?
A: Curt Lavender – We started with the uniaxial data, and from there the experimental parts (trays) were formed and stress distributions were determined from the trays.

Q: Mark Horstmeyer – Have any stress-strain measurements been made? Are you seeing recrystallization and grain growth in your models?
A: Curt Lavender – Yes, at higher strains, we have seen the formation of cavities which affect the material properties.

Q: Mark Horstmeyer – What is the path forward on fatigue issues?
A: Curt Lavender – We plan to do some biaxial formed trays to determine strain limits and determine the correlation with OEM data.

Q: What temperatures do the materials see in this process?
A: Curt Lavender – Temperatures greater than 400°C but below the melting point.

Q: Donna Walker – Have you considered the Bauschinger effect of changes in the stress-strain characteristics due to changes in microscopic stress distributions in the material, and how this affects the material during the superplastic forming?
A: Curt Lavender – I believe this is a limited effect since the material has virtually no elasticity at these temperatures.

Q: Donna Walker – Did you bench mark your model?
A: Curt Lavender – Yes, strain predictions were closely confirmed by physical measurements via gridding techniques on the actual formed parts.

Q: What about stress corrosion in forming the parts? Of the aluminum alloys, the Series 5000 aluminum alloy has best corrosion resistance.

A: Curt Lavender – The 5083 alloy is solution strengthened and we did not see this in forming the parts. Stress corrosion is an in-service or post-forming consideration, and is not a factor during the material manipulation.

Q: The 5000 series alloys are commercial alloys. Has any work been done on 6000 series alloys?

A: Curt Lavender – No one is working on the 6000 alloys now. Parts have been developed with superplastic forming with series 6000 aluminum alloys, but the parameters must be transferred to the mill. The alloys can be commercial if strength is sufficient.

Q: VK Sharma – The best application for superplastic forming is to replace SMC or plastic parts with parts made via this process, where weight is more of an issue than strength. Superplastic formed parts can also replace metal matrix materials, but there are barriers that must be addressed. For instance, suppliers must be recruited that are capable of developing the large parts, as an investment in processing must be made. To do this, a demonstration of these processes must document these cost and design savings and this documentation must be done in parallel with the demonstration. A new DOE program should show the application of these parts on vehicles in the field to ensure that these parts function as designed in an over-the-road environment. The program should demonstrate the benefits of these materials against its competition. This demonstration project should be jointly funded between the supplier and the OEM.

A: Curt Lavender – I agree: the supplier base still must be developed for superplastic forming to become a commercial process. We are hoping to encourage suppliers through this project.

Q: Robert Hathaway – The real benefit of superplastic forming is to optimize the aerodynamics of the vehicle, and achieving the new shapes required for the aerodynamic trucks. Information on the energy impacts of the process (efficiency gains in processing, energy efficiency improvements via aerodynamics or weight reduction) were not clearly provided in the presentation.

A: Curt Lavender – Some information shows that the combination of aerodynamic drag and weight represents 34% of the energy use of the truck. Mass reduction and part count reduction are also important.

Q: Tom Yonushonis – Are the aerodynamic characteristics of the finish details of superplastic formed materials being researched? What size parts can be formed?

A: Curt Lavender – No, gains in the energy efficiency were calculated based on aerodynamic styling only. Current studies are looking at the macro-level finishing issues, not down to part finishes at this time. There are presses available to do 10 foot by 20 foot parts. Box furnaces are now being replaced with other technologies, enabling increased part sizes.

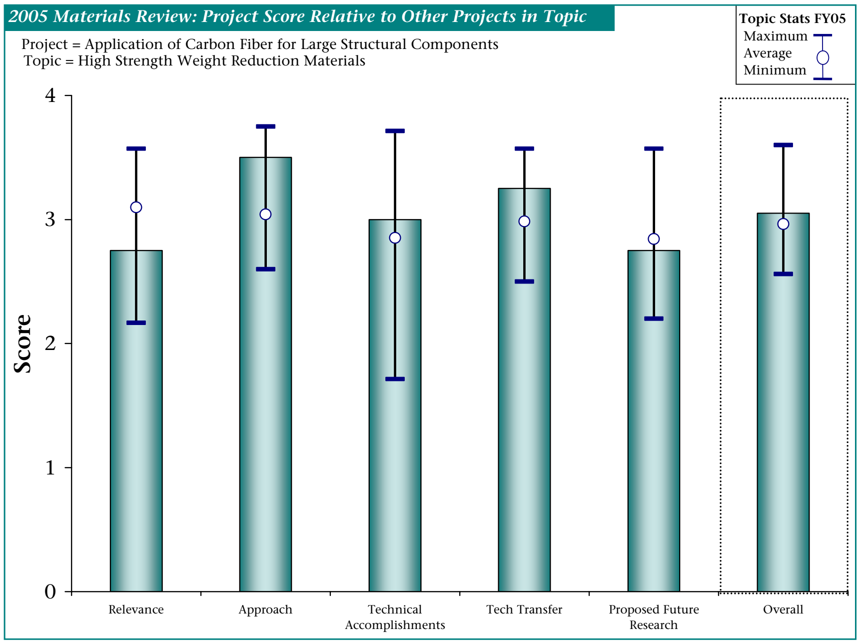
Q: Tom Yonushonis – How does the superplastic forming process compare to the other processes reported on earlier, specifically with respect to lifecycle analysis?

A: Curt Lavender – Not sure of any lifecycle analysis performed to date. Most of the applications for superplastic forming are for achieving complex aerodynamic styling shapes, with other processes performed to improve other material characteristics.

A: Mark Smith – The true competition for parts developed by the Superplastic forming process are SMC materials. This is a way to replace SMC parts and achieve a 40-45% weight reduction with recyclable materials (SMC materials are not recyclable).

High Strength Weight Reduction Materials

Application of Carbon Fiber for Large Structural Components; Kevin Simmons of Pacific Northwest National Laboratory



Brief Summary of Project

The objective of this project is to develop cost-effective, high-strength carbon fiber reinforced composites for large structural truck components that maintain Class A surface quality. The team is looking at blends of carbon fiber and glass fiber for reducing weight and cost.

Question 1: Relevance to overall DOE Objectives (Written responses from 3 of 4 reviewers)

Comments were favorable. One reviewer commented that the DOE objectives are met, and even a 30% weight reduction is anticipated. Another agreed, pointing out the weight saving of ~40% compared to SMC. The final reviewer noted that a significant weight reduction has been reached, but said that from the tone of the talk, it seems that the goal could have been even more ambitious.

Question 2: Approach to performing the research and development (Written responses from 2 of 4 reviewers)

One reviewer felt that the researchers have used a good approach. Another person noted that the mass savings and maintenance of Class A surface quality are challenges, which have been excellently solved by integrating design and process technology.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 1 of 4 reviewers)

A reviewer noted that the weight reduction has been achieved but still some issues with cycle times and cost remain.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 3 of 4 reviewers)

Two reviewers noted that the researchers have had good collaboration with the entire supply chain, including many industrial partners.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 2 of 4 reviewers)

One reviewer felt that the project is on track and close to finishing. However, another commented that they would have liked this program to be more aggressive.

Specific Strengths and Weaknesses (Written responses from 4 of 4 reviewers)

- Specific Strengths
  - Great weight saving potential.
  - Excellent combination of various disciplines needed to reach Class A and a weight reduction.
  - Excellent program, deserving to be even more forward looking.
  - Good technology transfer and collaboration with the chemical companies.
- Specific Weaknesses
  - Did not discuss the cost of the hybrid fiber compared to carbon fiber.

- No overview of competitive technologies.
- There are some shy points that can be easily improved.
- Again the cost of the fiber is an issue.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 4 of 4 reviewers)

- Combine experiences with those of RTM company SOTIRA France.
- The only recommendation I would make to improve the subject is, for the authors to also discuss possibility to improve the aerodynamics of their cabins and estimate the impact in terms of fuel savings.

Question and Answer Session at Review

Q: In regards to the fluid modeling – are these multi-phase models?
A: Others are working on the modeling, which is just starting now. They are using Polyworks software to develop the model for molding (a general purpose code).

Q: In your presentation, you referenced a "rapid" cycle time for modeling – is that the 12 minute time noted?
A: A total of 12 minutes are needed to fill and cure. The limiting factor is the fill time, not the cure time: the product can cure much faster.

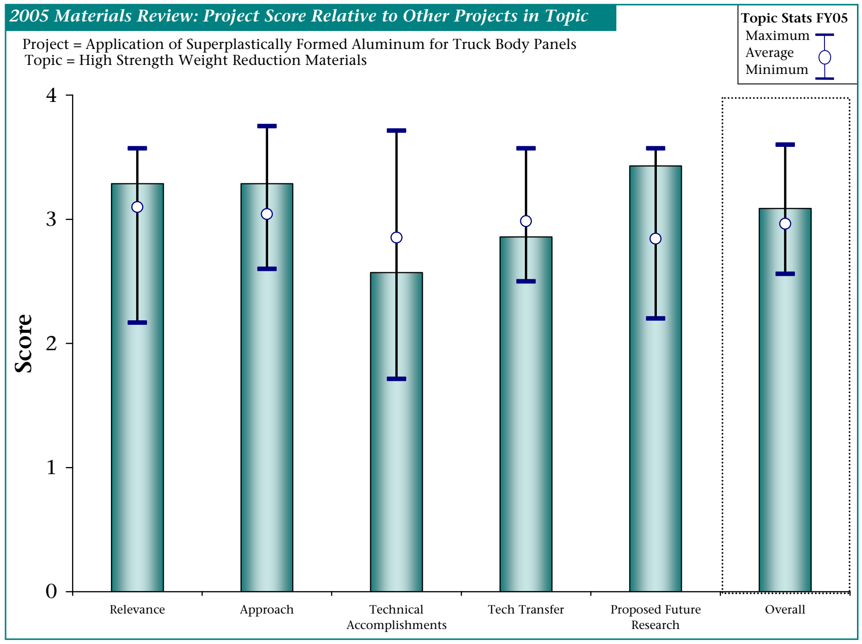
Q: You indicated in your future plans that you were trying to reduce cycle time further. What is your target for this process?
A: The manufacturer would like to achieve 5 minutes, but they realize that is pretty challenging to attain. Large parts (60 to 70 square feet) require 4-5 minute fills, so we are anticipating that we will be able to achieve a 15-minute time from start to demold for the part.

Q: What is the improvement in appearance between a standard finish versus a Class A finish?
A: With a standard finish, there is considerable glass and carbon print through. The finish quality is hard to quantify, and there is a lot of debate regarding the quality of a Class A finish. The quality of the finish also makes a contribution to overall aerodynamic drag (rougher finishes can increase drag).

Q: These processes seemed to be focused on low to medium volumes in the trucking industry. What are these volumes specifically?
A: Somewhere around 10,000 to 15,000 per year would be a good estimate. Total Class 8 truck volume is 300,000 units per year, so a level of 25,000 per year would be high.

High Strength Weight Reduction Materials

Application of Superplastically Formed Aluminum for Truck Body Panels; Nirmal Tolani of International Truck and Engine Corporation



Brief Summary of Project

This project will investigate applications of superplastic aluminum for low to moderate volume (up to 30,000 parts per year) body panels to provide a light weight and low tooling cost alternative to steel and SMC. The FY 2005 focus is to demonstrate the feasibility of superplastic forming technology for a large exterior body panel.

Question 1: Relevance to overall DOE Objectives (Written responses from 5 of 7 reviewers)

Several comments were positive. One reviewer felt that the benefits and barriers are well defined. Another commented that the project is component and process focused. One person felt that the project is aimed at increasing the application of aluminum into areas where traditional steel and SMC are preferred. The main opportunity is in low-cost tooling to compensate for the higher material cost, with a resulting benefit of significant weight reduction. As a contrast, one reviewer stated that no defined weight saving was provided. The final reviewer had very detailed comments and opinions. They said that the work is outstanding, especially since Volvo and International are considering discontinuing the manufacture of aluminum cabs due to new cab tooling costs. Thus, these manufacturers would go away from stamping of aluminum and move to steel, which is more or less taking a step backwards. SPF offers a solution to the tooling cost involved with stampings and the benefit of optimizing shape and stiffness of the parts through the incorporation of complex shapes during SPF. Medium-duty cabs are not concerned with weight. Tooling for aluminum is more expensive than for steel, so makers of medium-duty trucks are willing to use steel and lose the weight benefit.

Question 2: Approach to performing the research and development (Written responses from 3 of 7 reviewers)

One reviewer felt that the timeline is well defined with reasonable tasks. Another agreed with the straightforward approach, but noted that no effort is planned for reducing cycle time or making use of lower cost aluminum. The final reviewer suggested not starting with a "large" body panel, but perhaps starting on a smaller scale, showing success and then moving up from there. They commented that if the initial part demonstrated is too large to begin with and the project fails, the concept will be difficult to revive for the next 20 years; otherwise the approach is sound.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 5 of 7 reviewers)

Several reviewers noted that the project was initially funded in March 2005, but still has shown good progress. Others declined making a judgment since the project just started. The last reviewer felt the project was slightly behind schedule, but had a good chance to catch up.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 5 of 7 reviewers)

One reviewer noted that most work is being done by the prime contractor. Another person felt that this is a focused project whose output will provide demonstrated feasibility for specific component technology transfer. Another commented that the short term and long term availability of AA5083 has been researched and this alloy was found to be available. A supplier for tooling development has been selected and parts should be put into production in 2007. Others noted the limited outside involvement, which seems to be restricted to one OEM.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 3 of 7 reviewers)

One reviewer commented that a detailed plan was given that will result in introduction for the product. Another noted that the project is focused on aluminum SPF which will achieve 30-40% weight reduction over steel and fiberglass, which appears consistent with 21CTP goals. The final reviewer felt that this is a good project in response to the potential for industry to move away from aluminum stampings due to tooling cost for a new cab design. The weight advantage gained by aluminum can be maintained, if not improved upon, with SPF of aluminum. They feel that a combination of friction stir welding and SPF would be a good marriage of technologies.

Specific Strengths and Weaknesses (Written responses from 4 of 7 reviewers)

- Specific Strengths
  - Well directed toward addressing critical barriers.
  - Good.
  - Strong drive towards getting the technology application.
  - Focused project for a specific component.
- Specific Weaknesses
  - Not clear how/if process variables are being considered.
  - The project has a narrow base with respect to the choice of material and process. This could lead to a disappointment at the end without an insight in an alternative solution.
  - No cost comparison analysis other than general summary of material/process comparison.
  - Seems like an engineering application rather than scientific research or development of tools for widespread use.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 2 of 7 reviewers)

- Broaden the scope in the beginning.
- Should include a commercial forming source interested in productionizing SPF.

Question and Answer Session at Review

Q: Rogelio Sullivan – Are you planning to use existing alloys or are you developing a new alloy for this application?
A: Tolani – We are using an existing alloy (5083). We are using the least expensive alloy available for superplastic forming.

Q: Joe Horton – How thick are the resulting parts and how long are the processing cycles?
A: Tolani – Cycles have come down to 35 minutes for forming. Part thickness ranges from 1.5mm to 3mm.

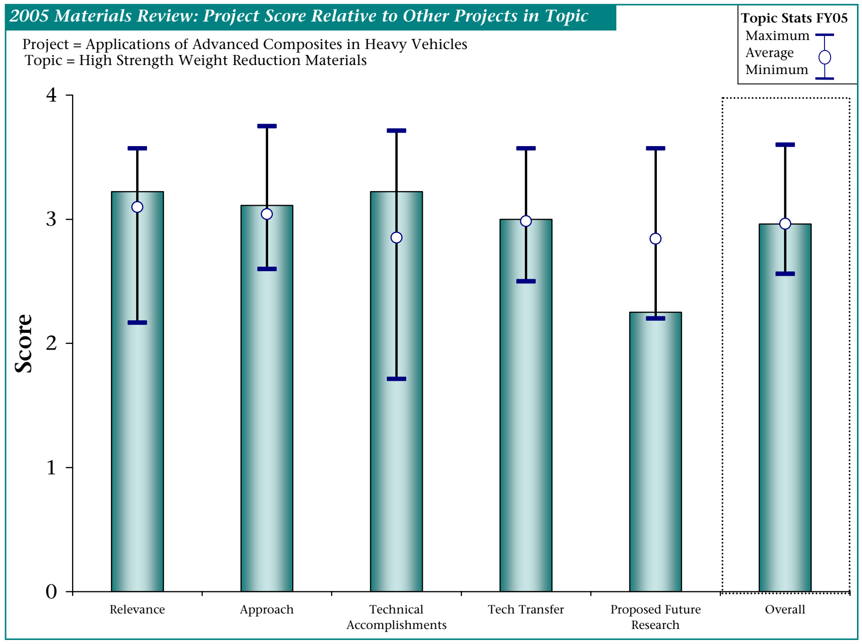
Q: How are models accommodating constant strain rates and complex shape deformations?
A: Tolani – Forming simulation was done by their suppliers, who have done this before.

Q: Dr. James Eberhardt – How does the aluminum body panel cost (especially tooling) compare with steel?
A: Tolani – The trucking industry cannot develop tools for two cabs, one for steel and one for aluminum. Most of the medium-duty market is weight sensitive: most are focused on lower costs. Only a small segment of trucking industry uses lightweight materials for increased payload. Aluminum tools are more costly, and separate tools are needed for aluminum and steel.

High Strength Weight Reduction Materials

Applications of Advanced Composites in Heavy Vehicles; Cliff Eberle of Oak Ridge National Laboratory and Curt Lavender of Pacific Northwest National Laboratory

Brief Summary of Project



The work discussed in this section is a combination of four individual project activities. The first project is to develop composite tie rods, trailing arms, and axles for auxiliary lift axle assemblies, reducing component mass by 50% and the lift axle assembly mass by 100 pounds or more. The second project is developing an economical and durable polymer composite Class 8 cab component with a 30% or greater weight reduction. The project also is looking to commercialize and produce cab components for a mid- or high-volume Class 8 tractor. The third project will develop carbon-fiber SMC technology that can provide Class A surface finishes for a truck hood that can be 30% lighter than conventional hoods. The fourth, and final, project is to develop and demonstrate (1) the application of hybrid composites and composite metal hybrid structures to heavy-duty vehicles and (2) the ability of these materials to be integrated into moderate-volume production vehicles.

Question 1: Relevance to overall DOE Objectives (Written responses from 6 of 8 reviewers)

One reviewer noted that when combined with other similar projects, they seem to fit very well into the goals of the DOE objectives. Another added that the project has substantial weight saving. One person commented that application of lightweight materials should be based on component performance and cost needs; these projects adequately address these requirements. Another commented that weight reduction is the main focus and it is easy to follow up the progress. One reviewer noted that the project has some weight savings which would help fuel economy but at a relatively high material cost. The final person commented that the project is basically using existing materials and processes (comment specific to project related to composite Class 8 cab component)

Question 2: Approach to performing the research and development (Written responses from 5 of 8 reviewers)

One person simply stated that this is an excellent integrated program. Another noted that approaches are complete in that design and manufacturing options are explored before physical parts are made. One reviewer felt that the researchers have used a good approach overall, but new processes need to be developed, rather than relying on mature technologies. One person commented that everything can be made better in the project, but it may require more funds. The final reviewer commented that the researchers need to consider the overall life of the component including the re-use of the material. They asked if aluminum would be a better material because of the residual scrap value versus a composite material.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 3 of 8 reviewers)

One person commented that the goals of the projects were met, in that weight was reduced and that the processes used can be implemented. Another reviewer noted that the researchers have demonstrated the ability to form components, but the cost of the fiber really kept them from fully using the technology. The final reviewer agreed that the technical barriers were achieved; however, the objectives were "low hanging fruit." This reviewer added that stretch goals should be set that include higher volume applications with new/advanced manufacturing processes.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 5 of 8 reviewers)

Several reviewers noted positive industrial partner interaction. One person commented that there were excellent industrial partners for all projects. Another agreed that industry partners were very involved in the projects, adding that the methods and processes can be used in production if and when the cost of materials comes down. Another singled out that Volvo was involved in many aspects of the program. One person felt that the carbon fiber price limited transfer. The final reviewer felt that OEMs need to be lobbied more aggressively.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 4 of 8 reviewers)

Several reviewers noted that the programs are at their end or nearing their end, so the future work would require relatively little "research" and more implementation by industry. One reviewer added that there are no significant future milestones for the project that was developing composite tie rods and other suspension components. Another noted that the future plans for the project related to a composite hybrid door assembly include developing/investigating manufacturing technology.

Specific Strengths and Weaknesses (Written responses from 8 of 8 reviewers)

- Specific Strengths
  - Weight reduction with reduced part cost. (Comment related to project developing composite cab component.)
  - Potential for high volume manufacturing, thin panels is a key! (Comment related to project developing carbon fiber SMC hood.)
  - Demonstrated possibility of carbon fiber SMC. (Comment related to project developing carbon fiber SMC hood.)
  - Excellent project, a hybrid structure is key, need more information. (Comment related to project developing hybrid composite door structure.)
  - Excellent comprehensive study to investigate hybrid materials. (Comment related to project developing hybrid composite door structure.)
  - Good program.
  - Most of the projects are very applicable to actual production.
  - Great demonstration of the components and the feasibility.
  - Excellent weight saving. Good integrated programs and good industrial partners.
- Specific Weaknesses
  - Manufacturing process is a mature technology. What was developed? (Comment related to project developing composite suspension components.)
  - Cycle time too high for high volume production. (Comment related to project developing composite cab component).
  - More details necessary, what were the hybrid materials? (Comment related to project developing hybrid composite door structure.)
  - (Super)light materials, such as carbon fibers are too expensive.
  - In the case of the carbon fiber SMC the filler material was not considered (or if it was it was not mentioned in the presentation.) If the goal is to reduce weight it would seem that a light weight filler material may give benefits.
  - Carbon fiber is too expensive for these applications at this point in time Payback is not there at this time. Payback time should have been calculated earlier in the project. Fiber costs increased which also caused issues with the project.
  - Cost of the carbon fiber seemed to be the main barrier for commercialization.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 5 of 8 reviewers)

- Investigate if cabs with composite components can be processed through e-coat tanks. (Comment related to project developing composite cab component.)
- Need for carbon fiber Class A SMC is a major need. Regardless of carbon fiber price, these materials are necessary to the transportation industry for weight savings. The process should be in place when/if carbon

fiber prices reduce. (Comment related to project developing carbon fiber SMC hood.)

- Investigate alternative light weight (non-composite) SMC. There is potential of up to 30% weight reduction. (Comment related to project developing carbon fiber SMC hood.)
- Additional focus is needed towards manufacturing processes to consistently produce and process hybrid components (Comment related to project developing hybrid composite door structure.)
- Overall - The biggest impact will be high volume application. Research in new processes and hybrid materials is necessary to support this. The programs presented were focused on low - medium production. More emphasis should be on high volume applications, regardless of carbon fiber price. If high volume processes are developed, the need for affordable carbon fiber will drive the price down. The potential use of carbon fiber in auto and truck applications dwarfs that of aerospace by orders of magnitude.
- Specific program to make (super)light materials significantly cheaper than what they are today. Should also be quantified as realistically as possible in terms of fuel savings.

Question and Answer Session at Review

Q: James deVries - What materials were used on the lightweight door?

A: Curt Lavender - Can't say specifically since this is confidential, but can say that it is made of two materials, one molded and one cast. Materials selected from the cost models were polymer and metallic materials, and fibers mixed with polymers. As the part was very complex, this complexity drove the manufacturing methods, and iteration was done to achieve cost targets.

Q: Rogelio Sullivan – The tie rods have been commercialized by Delphi already. Can they be used for front steer axle tie rods?

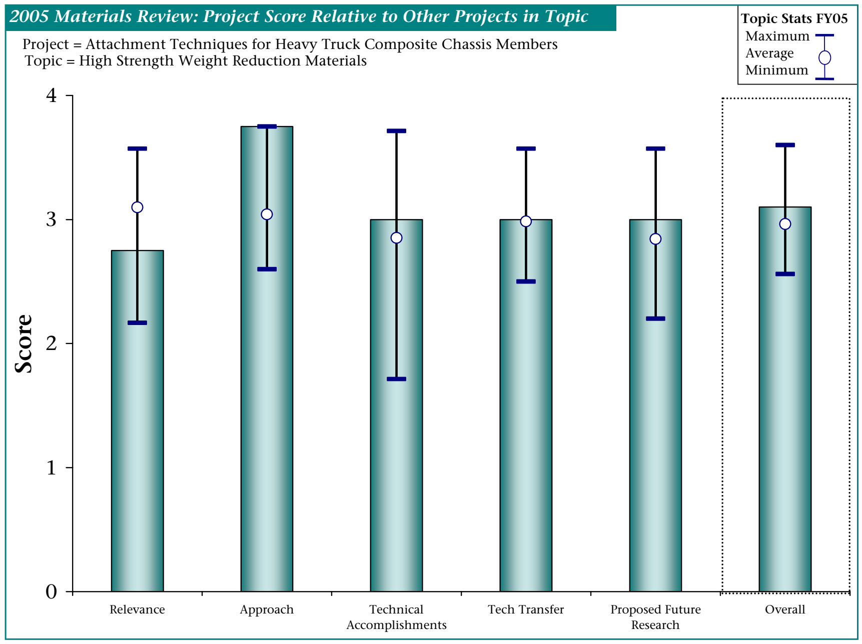
A: Cliff Eberle - Current fiber cost does not allow for commercial front tie rod applications. It would require much more material to meet the strength required to meet minimum safety specifications. Carbon fiber cost would have to be in the $4.50 to $6 range for a good commercial business case.

High Strength Weight Reduction Materials

Attachment Techniques for Heavy Truck Composite Chassis Members; Lynn Klett of Oak Ridge National Laboratory

Brief Summary of Project

The focus of this activity is to develop robust and economical joining techniques for lightweight polymer composite structural chassis components. This includes developing durable hybrid composite/steel joining concepts, testing composite and composite/steel joints in fatigue, and modeling the bolted joint interface utilizing progressive failure analysis.



Question 1: Relevance to overall DOE Objectives (Written responses from 3 of 4 reviewers)

One reviewer noted the good weight savings of 15-20%. Others felt that this can be regarded as an "enabling" technology. Although not directly impacting weight savings, this work is necessary to implement structural composite components. Another person added that when the result is positive, progress will be made with the introduction of composite chassis members.

Question 2: Approach to performing the research and development (Written responses from 3 of 4 reviewers)

Comments were positive to this question. One person commented that the researchers have used an excellent approach to address future implementation issues. Another reviewer commented on the use of both finite element modeling and mechanical testing. The last reviewer commented that using state of the art finite element calculations and well-thought-out experiments covers all aspects of the research.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 4 of 4 reviewers)

Comments were positive. One person noted the good work on a difficult problem. Another felt that this project has led to a good insight in the behavior of bolted joints with reinforced plastics. One of the reviewers noted the extensive tests from various aspects. The final reviewer commented that without this program, the project to develop economical, durable polymer composite support members for Class 7/8 trucks could not be implemented.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 4 of 4 reviewers)

One reviewer noted that the integration with future users that has been made part of the project is good, since this type of joining is most of the time done by the OEM. Another noted the researchers are working with finite element analysis and developing additional capability. However, one reviewer suggested there is a need to work more closely with OEMs. The final reviewer reiterated the fact that this is a necessary "enabler" program to other application programs.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 3 of 4 reviewers)

One reviewer commented that this program enables the composite support member project, but also more globally enables any structural applications of composites. Another felt that it clearly identified that bonding should also be taken into consideration, which has been incorporated into planning. The final reviewer asked about salt spray testing.

Specific Strengths and Weaknesses (Written responses from 4 of 4 reviewers)

- Specific Strengths
  - Excellent tests conducted from many different aspects.
  - This program will service numerous composite programs, not only structural.
  - Good methodical way of finding out the behavior of bolted joints.
  - Great scientific work on a difficult subject.
- Specific Weaknesses
  - Choosing a crossmember as a demonstrator will lead to problems because it is very difficult to replace this typical steel design without interfering with the characteristics of the entire chassis i.e. resulting in fatigue problems.
  - Unclear whether a resolution can be determined for the numerous issues with the attachment of composites to metals.
  - Balancing competing requirements for light weight, cost reduction and joining and machining issues.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 3 of 4 reviewers)

- Conduct salt spray testing to determine environmental effect.
- Close coordination of this program with all composite application programs must exist. Utilization of the results of this program should be demonstrated in the project to develop composite support members and/or other programs.
- Concentrate on a different component with less secondary effects.

Question and Answer Session at Review

Q: The effects of ratcheting and cyclic loading (especially in creep) have not been addressed here. Are they part of the GENOA software?
A: Lynn Klett – We haven't looked at it yet but will address this in the future.

Q: Have the different friction coefficients for different clamp loads for the bolts been examined?
A: Lynn Klett – Not yet, as the researchers have been trying to find a torque load where the composites are not damaged, this should be investigated further after the composite has been evaluated. Some studies have shown that painted steel can offer higher friction coefficients.

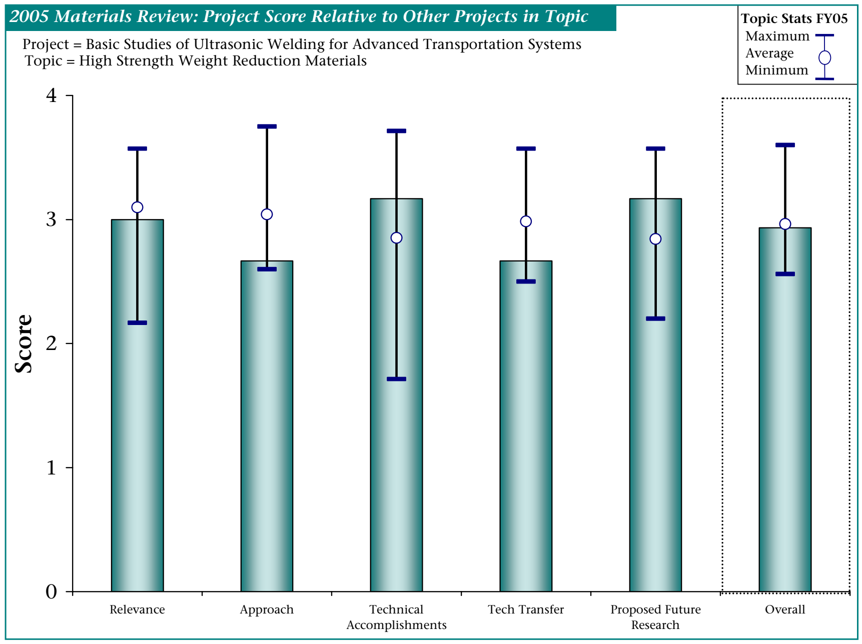
Q: What is the field experience with bolted joints with composites, with respect to creep and bolt holes?
A: Lynn Klett - An all composite wheel for a trailer has been developed in the Netherlands. This unit withstands torque loads twice as high as conventional wheels by using epoxy and found out that inserts are not needed – problems with torque loads were overcome by having more carbon fiber material to take the torque levels.

High Strength Weight Reduction Materials

Basic Studies of Ultrasonic Welding for Advanced Transportation Systems; Zhili Feng of Oak Ridge National Laboratory

Brief Summary of Project

In this project researchers are working to develop a fundamental understanding of the ultrasonic welding process. They are exploring opportunities for joining similar and dissimilar materials and exploring ultrasonic processing of materials in other novel and unique situations, such as low temperature consolidation of powder materials. The FY 2005 focus is on investigation of acoustic energy distribution during welding and exploration of low-temperature powder metal consolidation.



Question 1: Relevance to overall DOE Objectives (Written responses from 4 of 6 reviewers)

One reviewer felt that the program supports the DOE program well. Another added that it facilitates the use of lightweight materials. One person commented that this process seems to have many of the same advantages of friction stir welding but it may have other advantages that have not been exploited yet. The final reviewer commented that truck OEMs currently do not use ultrasonic welding, and added that they felt it is not clear how this project will contribute to weight reduction.

Question 2: Approach to performing the research and development (Written responses from 4 of 6 reviewers)

One reviewer felt that this is an excellent project to understand the basics of ultrasonic welding. Another commented that this is apparently a very new process which has not been fully investigated, so it is hard to know if the research addresses all technical barriers because they may not have all been identified. Others had comments on the research itself. One person commented that because of the size of the hardware near the welding point, the applications appear to be limited; however, this process may do well in conjunction with other welding technologies. The last reviewer pointed out that the presentation did not discuss continuous welds: the process seems to be limited to spot welding.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 2 of 6 reviewers)

Only two reviewers commented to this question. One felt that the project is on track to fulfill its agenda. The second reviewer felt that this project is apparently too new to be out of the laboratory so the industry applications have not been developed, but the possibility of joining dissimilar materials has great potential.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 3 of 6 reviewers)

One reviewer noted the collaboration with Ford. Another reviewer commented that the technology transfer at this time seems very limited due to the early development of the subject, but that the long term applications of the process are great. The final reviewer felt the researchers could do more in this area, commenting at this area needs to be developed for the program to fully succeed.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 1 of 6 reviewers)

Only one reviewer commented, stating that the future work appears to be “simply” additional development which seems very appropriate.

Specific Strengths and Weaknesses (Written responses from 4 of 6 reviewers)

- Specific Strengths
  - Novel ideas.
  - Ultrasonic welding and compaction (probably more so) are the strengths of the program.
  - Great potential.
  - Excellent basic research project. Will enhance understanding and utilization of ultrasonic welding process for dissimilar materials.
- Specific Weaknesses
  - Ultrasonic compaction was glossed over.
  - May not result in significant weight reduction.
  - Does not seem to be focused on any particular application or solving any particular problem for which industry has requested resolution.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 1 of 6 reviewers)

- Should be two separate programs.
- Potential benefits probably higher with ultrasonic compaction than with ultrasonic welding.
- Each of these two branches should be better focused.

Question and Answer Session at Review

Q: James Quinn – Do you have any performance data using the ultrasonic weld relative to other welds such as the resistance weld?
A: Feng – We do have some data for aluminum, and the ultrasonic process looks good.

Q: Rogelio Sullivan – Spot welding appears to be very similar to this process, how does it compare, specifically in the length of time to complete a weld relative to sheet thickness?
A: Feng – This process is very comparable with electric resistance welding, with the time to complete weld of about 1 second. We are now trying to get it down to 0.5 seconds. Electric resistance welding can be an issue with aluminum, however.

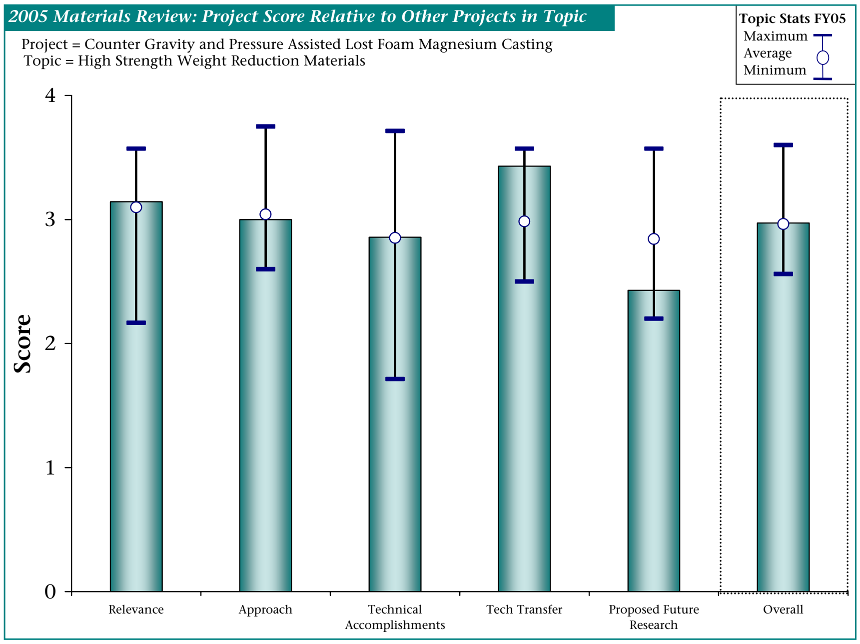
Q: Donna Walker – What frequency does this process occur at?
A: Feng – 20 kHz for the process.

Q: Rogelio Sullivan – Is 2 inches the ideal distance between the weld or the minimum distance between the weld?
A: Feng – This distance is about the minimum, as breaking of previous welds occurs if distances are smaller than 2 inches.

Q: Bob Larsen – You indicated that you are trying to join dissimilar materials. Are you attempting to join metals and non-metallic substances? Also, can this include joining metals to plastics?
A: Feng – We are not doing this yet, but are looking at joining metals to ceramics and metals to polymers.
A: Phil Sklad – This process is used in the plastics industry today so we are trying to bring it back to where it was first developed.

Brief Summary of Project

This project is focusing on evaluating the Hitchiner process and pressure assisted lost foam casting of magnesium alloys. The focus for FY 2005 is to develop melting and casting capabilities at Tennessee Technological University for lost foam casting of magnesium alloys, and to carry out experimental evaluations of the coatings and foam materials for magnesium lost foam casting.



Question 1: Relevance to overall DOE Objectives (Written responses from 4 of 7 reviewers)

One reviewer simply noted that the project goal is a 15-20% weight reduction. Another person felt that this program has the potential of having a substantial impact on 21CTP goals, but the timeframe necessary to bring the technology to manufacturing readiness may be too far off. One reviewer had detailed comments, noting that this project is focused on reducing weight of various low-stress, tractor-trailer components that would eventually lead toward improved vehicle fuel economy. To date the proposed manufacturing techniques are in an infancy stage, said this reviewer, and require substantial time and effort for maturation to the production of practical vehicle components. Nevertheless, this R&D effort is important since it does focus on reducing vehicle weight in a strategic manner that hopefully will not dramatically impact vehicle safety. The final reviewer stated that the key technical barrier was not clear; this reviewer asked why lost foam was used, and why the Hitchiner process would be examined. They wondered if there may be a good reason for this, but it was not communicated to the audience in the presentation.

Question 2: Approach to performing the research and development (Written responses from 4 of 7 reviewers)

One reviewer commented that this project is relatively new (one year old) and appears to be addressing the key research issues in a methodical manner including factors such as casting temperature, pressure, component type, and chemical effects. Another person felt that the work plan presented is sound and will attempt to address the technical objectives. This advanced project results in an understanding of the process and may result in substantial process improvements. However, even long term benefits to the truck industry are not well defined. Another reviewer pointed out that the researcher is using Procast to model the solidification process and should use the facility of Stan David to study the chemistry, hydrogen, and oxide density at different stages during the solidification process for lost foam castings. The final person wondered what the implication of density distribution was to the final properties of the casting.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 4 of 7 reviewers)

Reactions to this question were mixed. One reviewer noted that the progress to program goals is significant; however the long-range nature of this program limits the immediate returns of this program. Another person commented that performing the detailed density distributions comparing the aluminum and magnesium castings is a good idea. One reviewer acknowledged that this is a relatively new project and thus results/progress are inherently limited by the associated short time frame, but nevertheless, the principal investigators are accumulating knowledge concerning the optimization of casting both aluminum and magnesium foams including operating temperature, pressure, and gas composition. The final person felt it was unclear where the project is going to assist in DOE's goals.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 5 of 7 reviewers)

Reactions were positive in general, but some questions remain. One reviewer simply stated that the researcher showed great industrial collaboration. Another person felt that this project appears to have excellent industry and university interaction. For example, one partner donated equipment while another partner donated the "know how" of simulating one possible casting process. Another person agreed that clear collaborations appear to be ongoing with partners; however outside of the team the transfer is undefined. One reviewer noted that no names were provided of individuals from GM, Foseco, etc. so it was unclear whether a close coordination exists. The final reviewer commented that it seems that there are a number of users lined up but it was not clear how much contribution that companies are making to the project.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 5 of 7 reviewers)

One reviewer felt that the project future work effort makes sense (looking into different foams and coatings, and performing additional analysis to optimize the various casting processes). Another reviewer acknowledged that this program will provide a possible new manufacturing process, enabling another option for lightweighting, but the question is when it will be ready for industrial implementation. One reviewer wondered what the real application of the project is. Another reviewer commented that it was difficult to determine the use of the material from this project. The final reviewer felt that it was unclear what was actually going to be done, and suggested that interrupted tests during solidification be done to quantify the structure-property relations.

Specific Strengths and Weaknesses (Written responses from 4 of 7 reviewers)

- Specific Strengths
  - Good simulation.
  - This is a long range/high risk program that will not be addressed by current manufacturers. By definition, this is the type of R&D that needs to be addressed by National Labs.
  - Good list of partners to facilitate tech transfer and learning.
  - The principal investigators have equipment available to perform this R&D effort which is/was a major challenge with any experimental effort.
- Specific Weaknesses
  - Are there any real applications of your project?
  - This program may be too long range to affect the industry in the near term. Even if successful, is the infrastructure present or can be potentially developed. Magnesium die-casting is currently being successfully applied to a host of applications. Is the time and effort associated with this program worth the return, short term? Although I fully support this work, under the objectives of the 21CTP program, it is doubtful the effect on the industry by 2011.
  - Needs explicit statement of possible / likely application so mass savings can be quantified and evaluated rather than just proceeding in a general direction. Now seems too much like research for the sake of research and publication.
  - Limited applications for the process were detailed in this presentation. Indicates that higher quality casting can be obtained with the lost foam process.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 4 of 7 reviewers)

- Identify industrial applications.
- This program must continue, however under the auspices of the 21CT Program, is questionable.
- Would be helpful to add specific component as demonstration piece.
- It would be nice if the principal investigators could clarify which vehicle components are targets for the proposed casting technique.

Question and Answer Session at Review

Q: Mark Horstmeyer – Does degassing leads to lower density? The colors on the slide comparing densities of the plates are deceiving.

A: Han – The whole plate has higher density, and colors represent variance in density.

Q: Curt Lavender – What were the cover gases for the magnesium during this process? Also, how did you go about the degassing process?
A: Han – Both CO_2 and SF_6 were part of the gas environment. The only gas now used for the degassing process is SF_6. New approaches are being investigated and may be commercialized soon.

Q: Nirmal Tolani – What are the potential applications and parts for this process relative to die-casting?
A: Han – Die casting applications can be replaced with this process if density is a concern and a high quality material is needed. This is due to the highly turbulent flow of material in die-casting that leads to trapped gases and high porosity. This process removes gases that contaminate the part during the casting process and reduce overall porosity. The pressure assistance allows the metal to flow better in the casting.
A: Sklad - Housings and internal components require high quality material and are very good applications for this process. These parts have internal channels, which this lost foam process can do (versus die-casting).

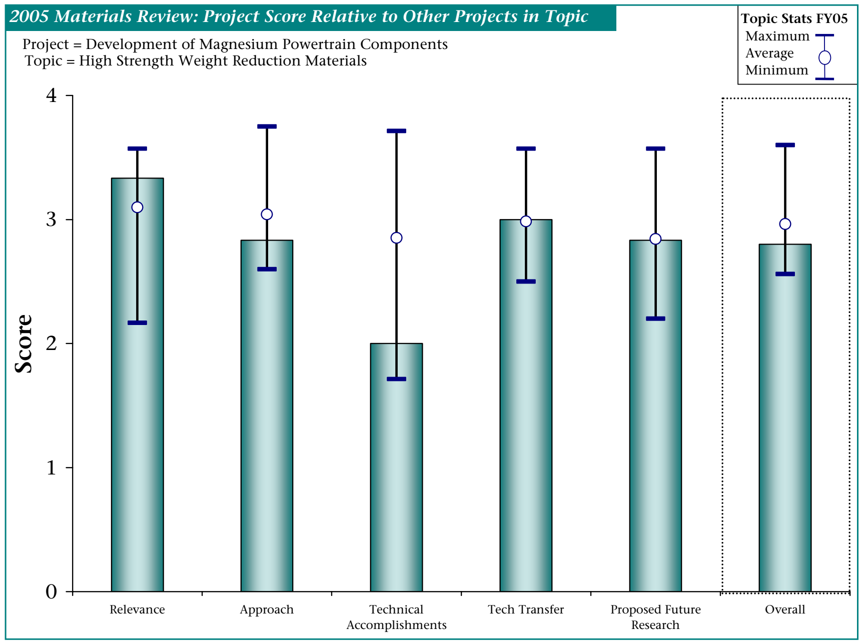
Q: Paul Becker – Hydrogen and other similar gases are more soluble in molten aluminum relative to the solid aluminum phase: is this also true for magnesium? This has been a problem in processing aluminum.
A: Han – Yes, in this respect, magnesium has very similar properties to aluminum

Q: Mark Horstmeyer – Did you observe bubble formation and translation in the material during casting and degassing?
A: Han – Yes, we did observe this. We reported this, as this effect seemed to be very interesting.

Q: Mark Smith – Magnesium is now being used as a commercial material, Ford is using magnesium die castings as the cross beams in the F150 pickup. This seems to indicate that commercial applications for magnesium are available with today's commercial processes. Are these commercial materials still porous?
A: Han – Yes, at the microstructure level. Degassing makes the end product more dense, which is not required for that particular beam, but is more applicable for other applications where material quality is much more important.

High Strength Weight Reduction Materials

Development of Magnesium Powertrain Components; Mark Smith of Pacific Northwest National Laboratory



Brief Summary of Project

Researchers are working in this project to develop magnesium composite casting technology and associated low-cost tooling for manufacturing of ultra-lightweight low-cost heavy-vehicle powertrain components Their FY 2005 focus is on evaluation of a modified lost-foam casting process that combines casting and compositing into one process step.

Question 1: Relevance to overall DOE Objectives (Written responses from 4 of 6 reviewers)

Two reviewers noted the significant weight saving (~10%) is anticipated. Another person commented that the researcher gave a clear argument for powertrain usage of metal matrix composites. The final reviewer added that this program addresses the need to find a cost effective metal matrix composite, and the focus starts with cost as it has to be.

Question 2: Approach to performing the research and development (Written responses from 3 of 6 reviewers)

Reactions were positive in general. One reviewer commented that the researcher has used a sound approach that was presented with measurable cost and performance targets, defining gateways. Another person felt that the researcher showed innovative approaches for local reinforcements in the matrix. Another acknowledged that the presentation indicated that potential applications are based on material characteristics, Also a focus should be given to low "after-cost" parts (avoid machining etc.). The final reviewer, however, felt that some of the details were missing.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 4 of 6 reviewers)

All of the reviewers concurred that it is too early to fairly judge progress of this project since it just started.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 4 of 6 reviewers)

Comments were positive in general. One reviewer noted the interaction with an OEM and casting suppliers. Another commented that the plan seems good with Mack Truck. Another person felt that the coordination with suppliers and the final customer is very clearly defined. The final reviewer felt that the supply base is very limited and it is not clear how this is solved.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 4 of 6 reviewers)

Two reviewers had similar comments, stating that the future work is clearly defined in an outstanding work plan. Another person felt that it is too early to determine the advantages of this work. The final reviewer felt that some details were missing, such as which metal matrix composite magnesium alloy will be used.

Specific Strengths and Weaknesses (Written responses from 2 of 6 reviewers)

- Specific Strengths
  - The best presentation of the day. A well organized work plan with well defined gateways. If the program

follows the plan and is successful, this could have a large impact on the 21 CT Program.
  - Starting with the low cost option will lead to an earlier introduction.
- Specific Weaknesses
  - Accomplishments to date are weak, probably because of this program just being less than a year old. Substantial progress needs to be observed in the next year so that this is more than a great presentation and work plan.
  - Involvement of Tier 1 suppliers is not certain.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 1 of 6 reviewers)

- Find a Tier 1 supplier.

Question and Answer Session at Review

Q: Rogelio Sullivan – What truck components are targets for this process?
A: Smith – Mack builds much of its vocational chassis (transmissions, hubs, suspension components, and drag links). Metal matrix composite materials are not especially ductile, but possess high impact energy and fracture energy. For this reason, we are looking at transmission cover plates and other chassis applications.

Q: Nirmal Tolani – What is the cost comparison of magnesium metal matrix composites to aluminum metal matrix composites?
A: Smith – We've been getting lower cost quotes for magnesium casting versus aluminum casting because of the market being flooded with material. The current price for silicon carbide is $1/pound, aluminum is $0.75-1 per pound, and magnesium is $1/pound. The cost of magnesium delivered to the casting point is around $2/pound. Finish machining can add costs, so the finished casting cost for magnesium is in the range of $2-3/pound.

Q: The project has jumped to magnesium metal matrix composites: should we focus on aluminum metal matrix composites first?
A: Smith – Mack is focusing on the magnesium technology, and DOE is focusing on the stretch applications of the technology.
A: Paul Becker – Aluminum composites are more short-term, and magnesium is longer term. It depends what the current DOE mission is relative to near term technologies versus longer term materials.

Q: Robert Hathaway – Aluminum metal matrix composites are difficult to machine and very costly, which is likely why they are not in the market. An issue with these materials is placing holes and threads within the material. Can this process improve upon the material properties of these modifications?
A: Smith – We can cast in holes for cover plates. For threaded holes and long bores, a selective reinforcement approach is more appropriate.

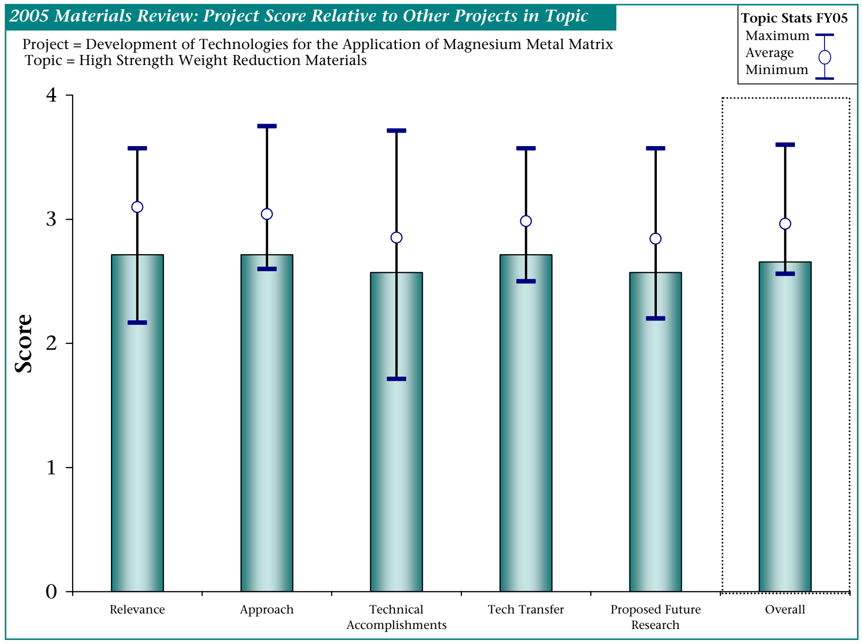
Q: Peter Blau – Back in the 1980s, the cost effective machining of ceramics was investigated and processes successfully developed. It appears that a similar action should be considered to develop cost effective machining of metal matrix composites.

Q: Jim Quinn – The discussion referenced the "design allowable matrix"; what is meant by this term?
A: Smith – This includes a combination of stiffness, ductility, yield strength, etc. for different alloys and processes.

Q: Jim Quinn – Quite a bit of foundational work has been done on silicon carbide as a reinforcement: would this work be applicable to magnesium, or would new work need to be done to determine appropriate sizes for the reinforcement additions?
A: Smith – We haven't looked at it so yes, I believe the impact of silica carbide size probably needs to be examined for magnesium MMCs.

High Strength Weight Reduction Materials

Development of Technologies for the Application of Magnesium Metal Matrix Composites for Heavy Vehicles; Adam Loukus of GS Engineering



Brief Summary of Project

This team is working to cast a magnesium alloy into a variety of ceramic preforms to attain promising mechanical and metallurgical results. The team has worked with squeeze casting and pressureless infiltration before designing process-controlled squeeze casting equipment. Their FY 2005 focus is on casting press design & installation, and casting metal matrix composites under a highly controlled atmosphere.

Question 1: Relevance to overall DOE Objectives (Written responses from 4 of 7 reviewers)

One reviewer noted that weight savings from the magnesium alloys have certainly been shown, but it is not clear if the weight savings results are sufficient. Another person liked the idea of studying the AZ91 magnesium alloy with the goal of improving properties. One reviewer noted that the project is mostly exploratory and seems to wander between silicon carbide and alumina preforms and squeeze casting and pressureless infiltration. The final reviewer commented that technically this program appears sound, presenting lightweight opportunities; however the first gateway should be whether or not a cost effective solution can be found.

Question 2: Approach to performing the research and development (Written responses from 5 of 7 reviewers)

Reactions were mixed on this question. One of the reviewers commented that a well-defined work plan is presented. Another person agreed, adding that the approach is very clear and concise. One reviewer noted that the technical barriers seem to be addressed but they do not seem to have been overcome yet. Another person commented that the program does not appear to be focused, but rather to be searching for potential methods to create magnesium metal matrix composite components. It seems to be more of a concept feasibility study without cost estimates. The final reviewer noted that the project is basically focused on reinforced squeeze cast magnesium materials, but noted that Lanaxide went out of business and it is not clear how this approach has benefits over their technology.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 4 of 7 reviewers)

Reactions to this question were mostly positive. One reviewer commented that the technical objectives are well defined and well aligned with DOE goals and a path to address these goals with proper gateways is manageable. Another person acknowledged that a fundamental understanding of a new material was clearly demonstrated. One of the reviewers noted that despite the lack of focus, the project is making strides and the development of a squeeze casting machine with ceramic preforms has potential. The final reviewer, however, felt that progress seems slow in this project.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 6 of 7 reviewers)

Reactions to this question were mixed. One reviewer noted that the researcher has partnered with Oshkosh and Eck Industrials. Another agreed that this project is well-leveraged via industrial suppliers and a final customer. The good work with universities and industry was noted by another reviewer. One person pointed out that the researcher does not have a magnesium company as a partner. Another reviewer felt that the program is in the initial stages and is more "concept feasibility" in nature. Therefore, it appears too early for technology transfer. The final person commented that it remains to be seen how the industry would pick up this work and implement it into production.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 5 of 7 reviewers)

One of the reviewers felt that the researchers have a good plan but a clearly defined corrosion study and investigations of mechanical behavior such as creep and fatigue and multi-axial effects are needed. Another felt that more emphasis on cost feasibility should be upfront to verify the impact on the industry; other applications need to be explored. One reviewer commented that it is too early to determine if this work has significance. The press is in the early stage of development and it is not clear if this project can lead to the low-cost high-quality components. Another person commented that once a process and a metal matrix composite have been decided, the program could advance to address cost and volume issues. The final reviewer felt that it is hard to tell based on the presentation.

Specific Strengths and Weaknesses (Written responses from 3 of 7 reviewers)

- Specific Strengths
  - Development of a new material.
  - Flexibility; the ability to evaluate different process and metal matrix composite variation to create a potential avenue for cost effective means of producing magnesium metal matrix composite components.
- Specific Weaknesses
  - This is capital intensive project. Cost benefit analysis needs to be conducted.
  - Other applications need to be explored. A 2 pound weight savings on the control arm may not be enough to justify the additional cost of magnesium as compared to aluminum.
  - Lack of focus and cost estimates.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 2 of 7 reviewers)

- Do studies on compression, tension, and torsion for monotonic properties and creep.
- Refine the focus of the project to identify a component, process, a metal matrix composite or ceramic preform and determine cost estimates.

Question and Answer Session at Review

Q: Mark Horstmeyer – Have you looked at tension/compression/torsion testing for the AZ91 alloy? Similar materials can result in very different stress strain results.
A: Loukus – That is an excellent idea to determine what these compression properties are.

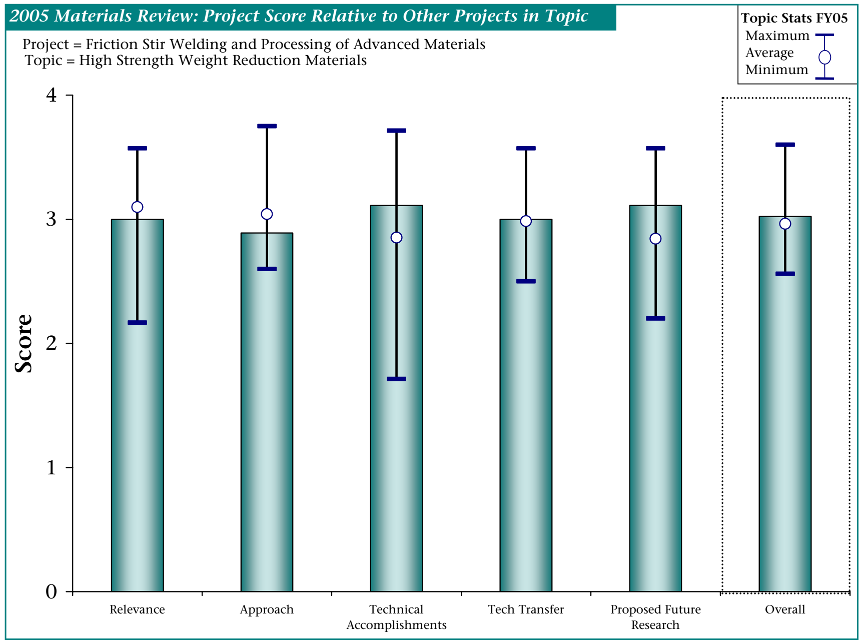
Q: Nirmal Tolani – Have you established a cost target for this material?
A: Loukus – We can sell this product in different markets for different prices. For example, the refuse truck and fire truck market, they are willing to pay $8 for each pound saved. In the military market for their heavy trucks, they are willing to pay $225 for each pound saved. In contrast the automotive market is only willing to pay $1.00 to $1.25 for each pound saved. As was shown in the presentation, we have developed pre-forms at a cost of $3 per pound saved. We won't establish a true cost target for this material until we select a specific component.

High Strength Weight Reduction Materials

Friction Stir Welding and Processing of Advanced Materials; Mike Santella of Oak Ridge National Laboratory and Glenn Grant of Pacific Northwest National Laboratory

Brief Summary of Project

The objective of the base project is to develop an improved understanding of the fundamental aspects of friction stir technology (a new manufacturing processwith a significant potential to facilitate wider use of lightweight materials). A CRADA project has been established with Ford to develop the friction stir technology as a viable candidate for construction of lightweight substructures for trucks and cars. Examples include engine cradles, suspension subframes, instrument panel supports, and intake manifolds.



Question 1: Relevance to overall DOE Objectives (Written responses from 6 of 9 reviewers)

One reviewer noted that the project has addressed the friction stir welding of different materials. Another person simply stated that the program focuses on engine system, parasitic loss, and safety applications. Another noted that this project will facilitate the use of lightweight materials. One reviewer felt that this project may open opportunities for manufacturers to specifically modify components to achieve higher engine efficiency. Another commented that the project will not lead to direct weight savings but can lead to increased use of lightweight materials resulting in lightweight vehicles. The last reviewer had detailed comments, stating that this represents a huge application potential for materials like magnesium that are difficult to weld. This reviewer believed the greatest benefit in friction stir welding is the ability to move away from arc welding and the stress concentrations produced that reduces a component's robustness. In addition, manufacture of large tailor welded blanks using friction stir welding is important. Lastly, the use of friction stir processing of component surfaces to improve the fatigue life and durability of a component is also important. Due to magnesium's mass reduction potential and its lack of use in the wrought state due to weldability issues, friction stir welding can have a significant impact on increasing the use of magnesium through our industry. This reviewer concluded by pointing out that 35% of magnesium is used for die casting, which is king in the automotive industry.

Question 2: Approach to performing the research and development (Written responses from 4 of 9 reviewers)

One reviewer commented that this work addresses the major concerns relative to the use of friction stir welding for light weight construction. However, during the presentation it became unclear that the choices were based on an evaluation, said this reviewer. One reviewer commented that the fundamentals learned in this project are important to furthering the technology so that it can be commercially implemented. Another person felt that the data showing how friction stir processing can improve the hardness of the magnesium for sealing surface/gasket applications was very interesting. The last reviewer was not clear how this will be applied or why it is that important, and felt that magnesium has limited application to heavy-duty truck and other applications.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 3 of 9 reviewers)

One reviewer commented that this type of work really illuminates the potential for friction stir processing, and is the type of work the DOE should be funding at the laboratories. Another noted that the work supports the innovation of surface improvement by friction stir welding: in this area, good progress was made. The last reviewer pointed out that the project defined AM60 magnesium alloy die casting friction stir processing parameters, showed grain refinement and characterized the resultant material properties.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 6 of 9 reviewers)

Reactions to this question were positive in general. One person noted that there were various industrial participants involved. Another person commented that OEM participation appears to be excellent. One reviewer noted the researchers established a CRADA with Ford on vehicle structure. Another reviewer commented that the partnering with Heil and Oshkosh Truck Corporation will go a long way in seeing the technology used on the road, supporting troops and our freedoms on tactical wheeled vehicles as well as improving heavy commercial truck mass reduction and fuel efficiency. They felt that the results are promising for working with engine related materials, and it will not be long before industrial partners approach Pacific Northwest National Laboratory to collaborate. The last reviewer simply noted the collaboration between Pacific Northwest and the South Dakota School of Mines and Technology.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 4 of 9 reviewers)

One reviewer noted that the plans to evaluate components will provide an excellent contrast to the performance of friction stir welding with coupons and will generate a better evaluation as to the barriers to implementation. Another person noted that the project results are being further used in a CRADA project. One reviewer felt that the chassis-less Heil tanker and friction stir welding would be a great combination of friction stir welding of aluminum and provide a very robust component; the use of a "self-reacting" friction stir welding tool (i.e., an unsupported tool) is ground breaking to bring the friction stir processing to OEM manufacturing facilities. The final reviewer commented that they would like the research team to choose a path and perform more detailed work.

Specific Strengths and Weaknesses (Written responses from 7 of 9 reviewers)

- Specific Strengths
  - Showed great progress in many areas.
  - Provides a methodology of joining inserts into magnesium, the self-reacting friction stir welding tool is very interesting. Surface processing of cast iron with TiB produces a very fine grain martensitic microstructure with TiB and TiC nanoparticles that can interact with dislocations and improve the wear resistance and resistance no doubt to heat checking. I really like how ORNL has evolved into the friction stir processing of ferrous materials and the incorporation of induction preheating to improve the tool life.
  - The combination of new innovative applications of friction stir welding with more proven applications.
  - Exploratory across a number of materials, magnesium, metal matrix composites, etc.
  - PNNL approach is very science based.
  - Great idea and good results.
  - Interesting processing technique that may have some applications in industry and truck applications.
- Specific Weaknesses
  - Seemed to jump around but that is OK with this type of exploratory process development.
  - Improvement is indicated but since this is an enabling project it should be more clear how much improvement has to reached to breakthrough barriers.
  - Not very focused, exploratory in nature, but plans to evaluate actual components will provide a better picture of the barriers to the implementation of friction stir welding.
  - ORNL effort seems somewhat "Edisonian" rather than science-based.
  - Does not appear that the approach will lead to major savings or performance improvements in the materials.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 4 of 9 reviewers)

- A machinability study in conjunction with these techniques would be very valuable. Once these potentially useful surface composite materials are made, they will need to be machined. A fundamental look at tool life would also be good.
- Introduce more validating type of testing for the friction stir welding surface improvement.
- Technical feasibility should give way to demonstrated feasibility so that technology transfer and implementation of FSW occurs.

- Give PNNL lead responsibility in friction stir welding and friction stir processing to focus the work and avoid what appears to be potential for redundancy between ORNL and PNNL.

Question and Answer Session at Review

Q: Mark Smith – Is the CRADA with Ford funded out of heavy vehicle materials funding?
A: Santella – Yes.

Q: Rogelio Sullivan – You discussed treating cylinder liners with some advanced materials to minimize wear, is this possible with friction stir processing? Typically, flat sheets are the demonstration parts for this processing.
A: Grant – Yes, machines have 3-D capability to follow complex curvatures; however, no one has tried to do this with steel due to heat and power issues. Friction stir welding is currently done on pipelines with very strong steels.

Q: Tom Yonushonis – Has this technique ever been applied to valve seats?
A: Grant – Not yet, but it is a simpler geometry than cylinder liners and should be possible.

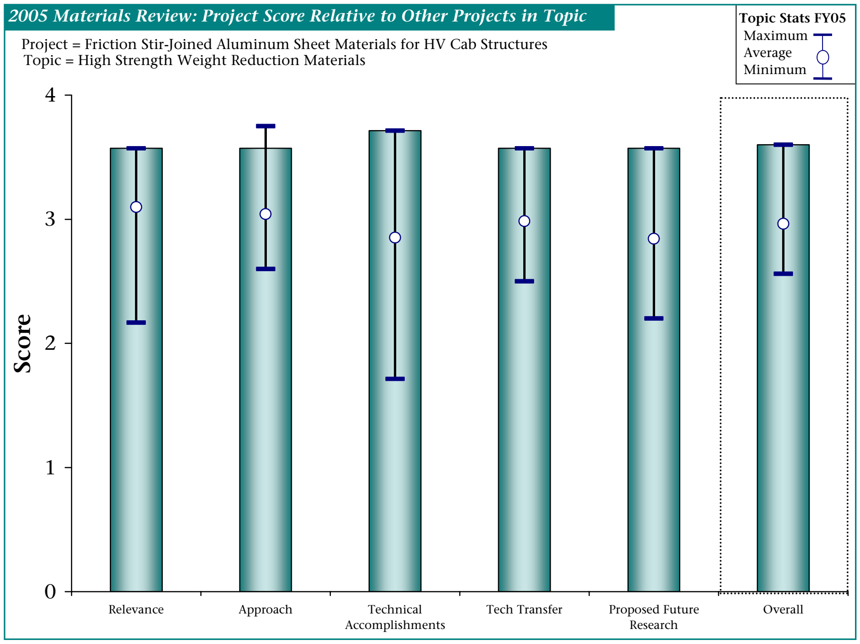
Q: Rogelio Sullivan – Is there any tool development going on within this project?
A: Grant – During the initial project phase, tool development was required for the metal matrix composites, but now we purchasing the tools from commercial suppliers.

Q: James Quinn – Can you weld in the interior of parts rather than on the exterior, especially with complex curved parts like the interior of a cylinder bore?
A: Grant – Yes, Siemens has used an internal friction stir welder for pipeline welding. The tool is slightly modified and has a curved shoulder which is smaller than the internal radius of the part to be welded. This is done to ensure the edge of tool never contacts the edges of the welded material.

Q: Nirmal Tolani – Can you tell us some of the manufacturers of these friction stir welding tools?
A: Grant – There are three that we use: Advanced Joining Technologies (a California company that is a Boeing spinoff), Friction Stir Link, and a third supplier located in Minnesota. There is not currently a very well-defined supplier network for these systems. Airbus is using friction stir welding on its A340 and A350 planes, and some small jet companies are using friction stir welding for all joints in the aircraft.

High Strength Weight Reduction Materials

Friction Stir-Joined Aluminum Sheet Materials for HV Cab Structures; Glenn Grant of Pacific Northwest National Laboratory



Brief Summary of Project

This team is working to develop and deploy friction stir joining (FSJ) as a weight and cost-saving manufacturing technology for heavy vehicle cab structures. The FY 2005 focus for this project is to develop tool designs and FSJ process parameters that lead to stronger, more formable, and lower cost welded blanks, and to develop appropriate techniques to join similar and dissimilar aluminum alloys of specific interest to project partners.

Question 1: Relevance to overall DOE Objectives (Written responses from 3 of 7 reviewers)

One reviewer noted that the project goal was to save 20-25% in weight. Another person felt that a more complete analysis of potential energy savings would be useful. The last person felt that the applications of friction stir welding can be used in many areas that have yet to be exploited.

Question 2: Approach to performing the research and development (Written responses from 2 of 7 reviewers)

One reviewer commented that the approach focuses very well on meeting the objectives of the project. Another person felt that the problems associated with joints between sheets of different thickness deserve more attention.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 2 of 7 reviewers)

One reviewer simply noted that excellent progress has been made. Another person felt that the results of the work show that this process can be very versatile. If used to its potential it could significantly change many components.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 5 of 7 reviewers)

Several reviewers noted the good collaborations; one saying the collaborations with Freightliner and various suppliers is very important and can be used for future work. One reviewer felt that Dr. Grant did not really elaborate on technology transfer, so the situation may be better than this reviewer's overall rating. The last person noted that the researchers are working closely with end users and that they understand the key issues.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 1 of 7 reviewers)

One reviewer commented that additional work with suppliers and industry can make significant improvements.

Specific Strengths and Weaknesses (Written responses from 6 of 7 reviewers)

- Specific Strengths
  - Good progress.
  - Sound, logical technical approach.
  - Good application of scientific principles to engineering process.

- Top notch program.
- This appears to be a very useful process that can have many applications.
- Excellent project to commercialize friction stir joining.

- Specific Weaknesses
  - How can a supply base be developed?

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 2 of 7 reviewers)

- Don't overlook joints with different thicknesses.
- Should be encouraged (with more funding) to do even more and perhaps faster.

Question and Answer Session at Review

Q: VK Sharma – What is the weight reduction target?
A: Grant – If it is applied across the entire cab structure, 15- 25% weight reduction can be obtained. Savings on a part-by-part basis can differ: doors could be up to 50% lighter.
A: Mark Smith – This weight reduction is based on tailored blanks replacing aluminum blanks – replacing steel can save an additional 100 to 150 pounds.

Q: Donna Walker – Why did failures occur on these joints?
A: Grant – For hardened alloys, it appears that failures occur due to the weld being more ductile than the parent sheet. However, on dissimilar materials, there is need to learn more to understand the reason for the failures, but mixing of the materials in the joint may be an issue.

Q: Mark Horstmeyer – For the small tensile testing, how was the size of the test nugget determined, given the gradients of properties in specimens longitudinally down the weld?
A: Grant – All nuggets are longitudinal. Studies have been performed on how large the size should be. This test nugget size is 4 microns, based on the equipment available. Sheet materials have much larger grain sizes, but good results can still be obtained.

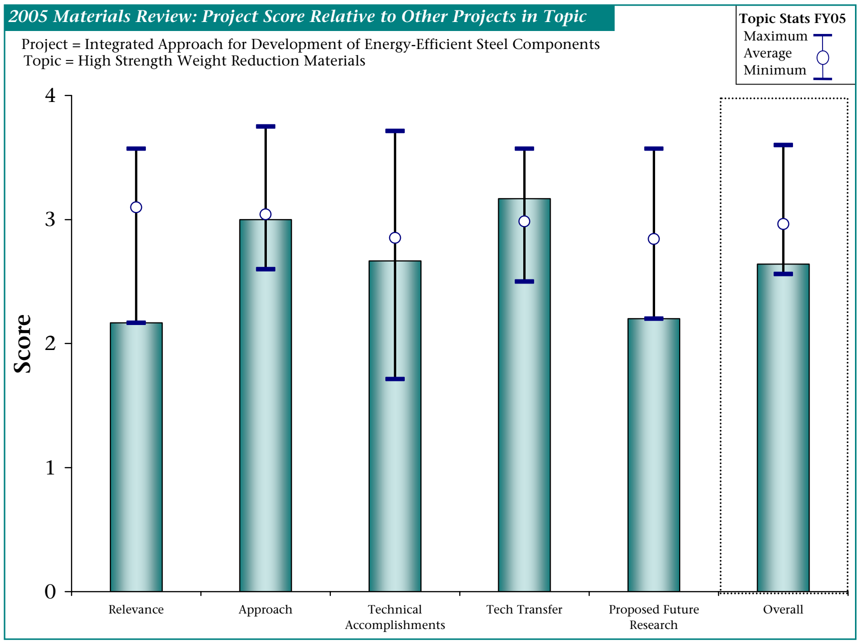
Q: Peter Blau – What about automated ball indenter testing of stress/strain on the miniature specimens?
A: Grant – This technique has good agreement with other methods on ultimate stress and strain to failure, but assumptions need to be made on the ball testing method to determine other parameters.

Q: Mark Smith – Weight savings are achieved with replacement of aluminum replacing steel. Even more savings can be achieved if the replacement aluminum is a tailor welded blank, and cost savings can be achieved through not paying for extra metal in the blank where it is not needed.

Q: Ray Fessler – Can you use materials with differing strengths in a tailor welded blank, or could you use different thicknesses of the same material in a blank?
A: Grant – It depends on the part application, and what is to be achieved (strength, appearance, etc.)

High Strength Weight Reduction Materials

Integrated Approach for Development of Energy-Efficient Steel Components; Leo Chuzhoy of Caterpillar Inc.



Brief Summary of Project

Researchers are working to develop tools to simulate the formation and influence of non-homogeneous microstructures in steel processing, to demonstrate the techniques developed for a defined component, and to develop methods and tools to produce energy –efficient steel components. For FY 2005, the focus is on formation and influence of non-homogeneous microstructures during and after heat treatment processes.

Question 1: Relevance to overall DOE Objectives (Written responses from 6 of 6 reviewers)

Reactions to this question were mixed. One reviewer felt that the project addresses increasing the efficiencies of processes and improving simulation capabilities. Another person felt that this is an excellent technology program, but does not appear the project will have significant contribution toward 5,000 pound weight reduction goal. Another person commented that there is a potential weight, cost, and resource saving, but it was not defined in the presentation. Others were more critical of the work. One reviewer commented that it is not clear how, or how much, this project will affect fuel efficiency. Another added that it is difficult to determine how this will result in energy savings. The final reviewer felt that the project is too theoretical with no significant practical value.

Question 2: Approach to performing the research and development (Written responses from 2 of 6 reviewers)

One person stated that if the goal is to improve simulation processes, it is difficult to criticize the approach because simulation is such a basic part of the project. This reviewer noted that the transfer to industry and the development of actual parts are also being done, which makes the approach justifiable. The final reviewer commented that the description of the approach was so vague that it was not possible to understand the approach; the models should have been described in terms of input, output, and benefits.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 3 of 6 reviewers)

One person felt that the researcher showed impressive modeling results. Another noted that the process is being expanded into industry which is consistent with DOE goals. The last reviewer felt that the description of results was too vague to judge their value. The reviewer questioned whether there were any new compositions, heat treatments, or other processes developed. They also questioned whether the performance has been improved, and if so, how this relates to energy savings.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 2 of 6 reviewers)

Reactions were mixed to this question. One person noted that according to the presentation there is direct transfer into industry, while another commented that no collaboration and tech transfer was defined.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 1 of 6 reviewers)

One person commented that the implication of the presentation is (or the impression that they got from the presentation is) that work is going to continue to develop and the developments will be made public.

Specific Strengths and Weaknesses (Written responses from 2 of 6 reviewers)

- Specific Strengths
  - Fundamental approach to understand relationships among processing, microstructure, and properties.
  - Good manufacturing engineering technology program.
- Specific Weaknesses
  - Potential benefits and path to those benefits are not clear.
  - It is not clear how much impact the project will have on the weight reduction goal

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 2 of 6 reviewers)

- Explain how work might lead to energy savings.
- Consider predicting and including residual stresses in the simulation.

Question and Answer Session at Review

Q: Paul Becker – In cast iron, the amount and size of graphite is important; is that part of the simulation?
A: Chuzhoy – Yes, we are looking at graphite morphology.

Q: Paul Becker – Since there are three different types of cast iron, do you plan to model other cast irons beside gray cast iron?
A: Chuzhoy – We would like to model the other two cast irons, but have no plans at this point.

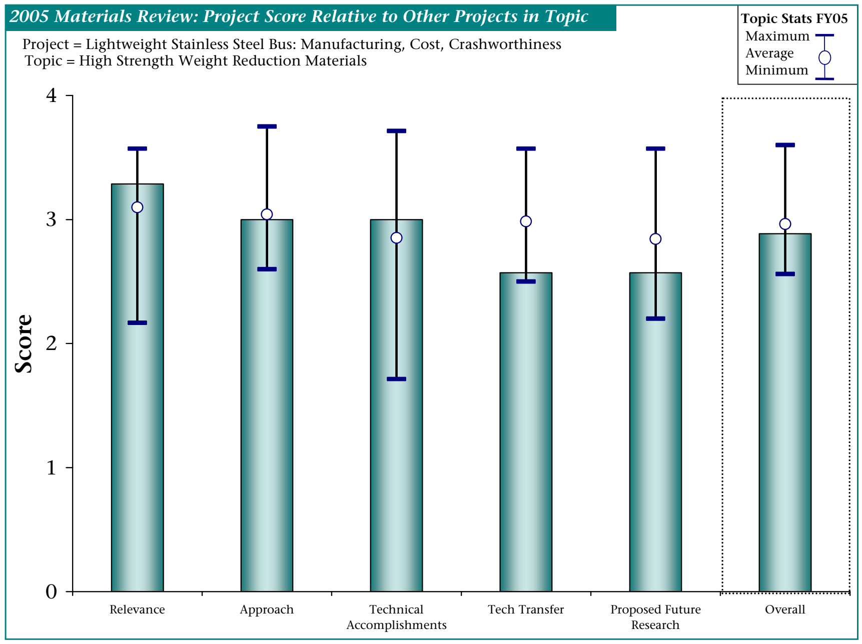
Q: Mark Horstmeyer – Is there a Bauschinger effect in the material?
A: Chuzhoy – Yes, quite a bit in the machining process.

Q: VK Sharma – Changes in the microstructure cause residual stresses that can affect life of the part; are you including this in the analysis?
A: Chuzhoy – Yes, this is included.

Q: Robert Hathaway – Is the simulation program available to other companies?
A: Chuzhoy – We will publish all work we are doing, Caterpillar is working on one specific methodology that is commonly available. Brown University has the software, and Caterpillar does not prohibit Brown from distributing the software code.

High Strength Weight Reduction Materials

Lightweight Stainless Steel Bus: Manufacturing, Cost, Crashworthiness; Bruce Emmons of Autokinetics



Brief Summary of Project

This team is working to investigate and demonstrate the mass saving potential of ultra-high-strength stainless steel as applied to the structure and chassis of a full-size urban transit bus. The FY 2005 focus is on detailed design of suspension, and final assembly of body structure and suspension.

Question 1: Relevance to overall DOE Objectives (Written responses from 6 of 7 reviewers)

One reviewer noted that the group has targeted approximately 50% weight reduction and a threefold improvement in fuel efficiency. Another reviewer felt that this project focuses on a key DOE area of interest using lightweight high strength structural materials and has shown preliminary positive results toward the practical applicability of stainless steel for a bus structure. One person commented that while the project clearly addresses the DOE goal of increasing fuel efficiency, it is not well focused. They added that the objective specifies the mass-saving potential of high-strength stainless steel, but the approach includes many other factors including changing to an electric propulsion system and eliminating air conditioning, and there does not appear to be an effort to separate the effects of the various factors. Another reviewer commented that the objectives fit well in that weight and fuel savings; they added that the assembly processes and materials are not novel (although the application may be). One person noted that the application of stainless steel for bus frames is well outlined, but the means by which components will be manufactured (prototyped) was not provided in detail. The final reviewer pointed out that the work is relevant to obtaining light weight bus applications, although it is not clear what is difficult in this work. It seems to be more or less off-the-shelf technology that industry could pick up if there was an advantage.

Question 2: Approach to performing the research and development (Written responses from 5 of 7 reviewers)

One reviewer felt that overall the approach is very good, including elements of structural multi-dimensional stress analysis, assessment of side impact (safety), and projection of possible fuel savings versus a standard comparable bus. The reviewer added that more effort could be spent on front end collision assessment (maybe the principal investigator has undertaken this matter but didn't have time to report such analysis) and also more accurately assessing potential fuel savings gains through expansion to various duty cycles. Another simply pointed out that the researchers conducted testing and non-linear finite element analysis. Another reviewer commented that the project is mostly an exercise in finding applications for stainless steel in bus applications and stainless steel bus design; they felt that this is a good starting point but manufacturing feasibility is left unproven. Another stated that they felt that the approach is logical but does not seem revolutionary. The final reviewer commented that the project will not be successful unless it results in a credible demonstration of the cost-effectiveness of the concept, and that will require a reasonable estimate of the total cost of the vehicle and "apples-to-apples" comparisons with other technologies. The comparisons of cost and weight savings are not valid because the baselines are significantly different from the concept vehicle: one baseline considers a stainless steel bus and another considers a carbon steel bus. All costs need to be included. A factor of 4 cost savings in manufacturing costs needs to be justified. Also, the threefold improvement in energy efficiency needs to be explained.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 5 of 7 reviewers)

Reactions to this question were mixed. One reviewer noted that there has been good progress on finite element analysis and on use of stainless steel. Another felt that there has been good engineering analysis of the bus structure and the vehicle performance along with fair analysis of the cost associated with using stainless steel material for the structure. This project has shown a good technical likelihood of success in demonstrating the potential for stainless steel as a vehicle structure but it is unclear if such a material is truly practical for an automotive or medium-duty application from a cost perspective. Others were more critical. One reviewer commented that the accomplishments sound good but it looks like most of the work to date is computer generated with relatively little physical hardware produced. Another person noted that rapid progress has been made in construction of a prototype, but noted that little progress has been made toward understanding the importance of stainless steel or the total cost of such a vehicle, which is critical to establishing a business case. The last reviewer commented that process information for manufacturing stainless steel components is not well defined.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 5 of 7 reviewers)

One reviewer noted that the researcher is currently seeking licensing and investment with multiple bus manufacturers. Another person felt that the project has done a great job of suggesting a lightweight, crashworthy bus design. Now it is desirable to prove that the design could be manufactured cost effectively. One reviewer noted that the nature of this project doesn't strongly rely on very close interaction with industry and felt that the next phase of work experimentally assessing crashworthiness, vehicle performance, and a more detail cost analysis may or may not encourage more industry interaction. Another reviewer commented that it seems that the work would transfer very well into actual use. The modeling and software would be very useful. The cost of the stainless steel may limit its use but the design principles can probably apply to other materials. The last reviewer felt that the work appears to be largely independent work without significant supplier or national lab involvement.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 4 of 7 reviewers)

One reviewer commented that future effort will focus on building a prototype and assessing its structure and vehicle performance. They felt that it is critical that the principal investigator fairly assesses fuel economy over various duty cycles and also eventually assess crash worthiness. Another person noted that the project is scheduled to end in December 2005, so hopefully someone will carry this work further. Although having a stainless steel bus design with suggestions for propulsion is interesting, it is more of interest to see if the stainless steel component design could be implemented in bus-like applications to achieve 21CTP goals. Another reviewer felt that more emphasis should be placed on credible comparisons with appropriate base lines and on developing information that will be needed to establish a business case; air conditioning also needs to be considered in any comparison. The final reviewer simply stated that it does not seem that this has any research aspect.

Specific Strengths and Weaknesses (Written responses from 6 of 7 reviewers)

- Specific Strengths
  - Good integration of design, testing, and finite element analysis.
  - Considers entire vehicle system.
  - Proved design feasibility with respect to weight and crashworthiness.
  - Good large scale demonstration of viable technology.
  - Significant weight savings, fuel savings and cost.
- Specific Weaknesses
  - Lack of understanding of individual factors. Inappropriate base lines for comparisons.
  - The project leaves you hanging with minimal details in the stainless steel processes and potential to implement the design.
  - Too little validation of performance predicted in the computer aided engineering work and the presentation doesn't address vehicle performance comparison to conventional buses.
  - Lack of interaction with a propulsion partner that can accurately assess the light weight bus performance.
  - It seems that relatively conventional processes and materials are used. Also most of the work done to date appears to be "on paper."
  - It is not clear what the research portion of this program is. It appears to be off-the shelf technology. It is

not clear what is difficult to solve since it seems like this is basically an application of current materials technology.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 4 of 7 reviewers)

- More emphasis should be placed on credible comparisons with appropriate base lines and on developing information that will be needed to establish a business case. In addition, air conditioning needs to be considered in any comparison.
- See if future work could utilize some or all of the design work for specific components.
- Do more test of actual components, assemblies, etc., rather than relying entirely on computer-aided engineering and projections.
- It is critical that the principal investigator fairly assesses fuel consumption of the prototype bus along with crashworthiness - both items should be carefully planned and assessed in the future.

Question and Answer Session at Review

Q: Mark Horstmeyer – In your test plan, did you do any validation of your modeling?
A: Emmons – Yes, there were a number of aspects to the test. Modal tests on the structure (including glass) were done. Preliminary static tests simulating the APTA static tests were also done. Additional funding will be needed for full Altoona testing. Crash testing hasn't been done on this first bus, but will be done once we begin working with a manufacturer.

Q: Nirmal Tolani – Have you performed any stress corrosion tests to determine if there will be any failures? This may be an issue with cold-worked stainless steel.
A: Emmons – The steel company developing the Nitronic 30 stainless material did many tests on coupons and welds. The material was also tested using a high temperature salt corrosion test.

Q: Bob Larsen – In regards to crash testing, have you investigated a frontal impact? It appears that a frontal impact will expose the bus batteries to damage, which looks to be a serious issue.
A: Emmons – We have incorporated a unique front crash absorbing structure, adapted from auto applications. This is a very efficient energy absorber. We do not have any funding for crash testing. Frontal testing has been ignored in bus testing as bus manufacturers have typically provided large front structures as a protection for the bus. The danger for bus passenger fatalities is very low for front impact: fatalities typically occur in the other vehicle.

Q: Bob Larsen – In regards to performance, it appears that 120 kilowatts of continuous power may not be adequate to achieve similar performance to a conventional bus, given its weight. What will the range be?
A: Emmons – Performance should be similar to a standard bus. Torque curves and acceleration curves exceed conventional bus at low speeds. Top speed of the hybrid bus is 70 mph. The bus has met gradeability requirement of 16% at its top speed of 70 mph, which is a great leap for electric buses, most of which can only achieve 16% grades at 50 mph. Range is uncertain due to air conditioning considerations. Since the vehicle is so efficient otherwise, the air conditioning system can use a significant portion of the available energy. A diesel generator on board can operate the air conditioning, extending the all-electric range. Range without air conditioning operating on all electric is 150 miles.

Q: Bob Larsen – Did you use GREET for this simulation?
A: Emmons – Yes.

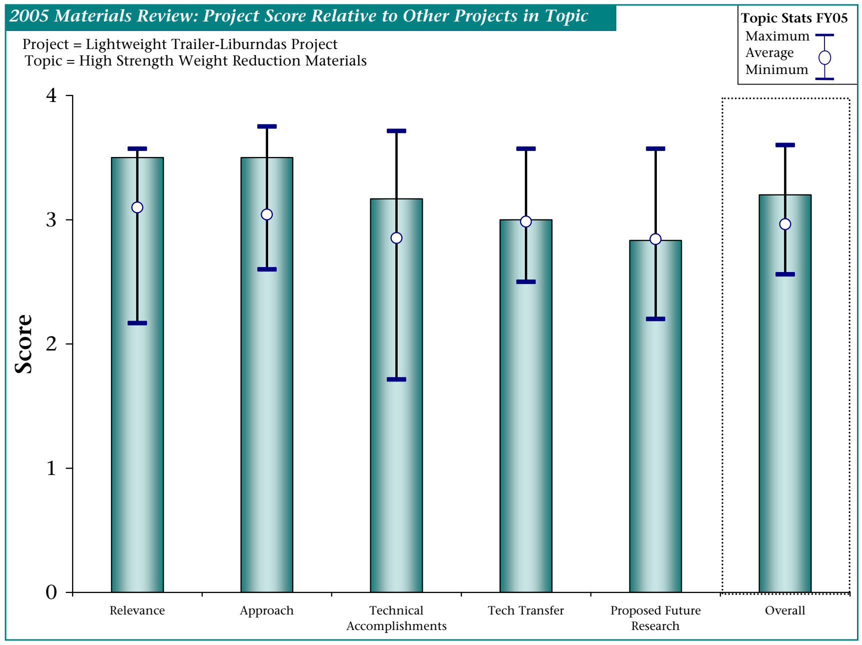
Q: Ray Fessler – The design is impressive, and the system looks good. With this design, a comparison to a conventional bus is very difficult, however. How much of the cost and weight savings is due to using stainless steel versus other improvements (engine replacements, aerodynamics, and so on)? What would the result be with a high-strength carbon steel bus design?
A: Emmons – There has been much investigation into the benefits of high strength stainless steel. The conclusions drawn from these analyses was stainless steel can save more weight and cost less than standard steel due to the reduction in processing costs of stainless steel as well as the inherent corrosion resistance of stainless steel. Also, stainless steel is a much easier material to work with due to the material properties of

stainless. Sourcing of benefits for stainless steel in this design is difficult to determine. Benchmarking was never completed as NovaBus ceased production of the NovaBus RTS baseline. There was no benchmark information available from NovaBus on the weight of the baseline bus. It was decided to design a fully optimized bus as the path forward.

Q: Ray Fessler – What is the total cost of a conventional bus versus your bus?
A: Emmons – We have only done a cost comparison on the bus structure. The selling price for a conventional bus is about $375,000.

High Strength Weight Reduction Materials

Lightweight Trailer-Liburndas Project; Ben Ubamadu and Kevin Tumlin of Heil Trailer International



Brief Summary of Project

This project's goal is to reduce the aluminum tank semi-trailer's net weight by 20% by redesigning the vessel to a cylindrical shape and by using available composite technology for functional components.

Question 1: Relevance to overall DOE Objectives (Written responses from 3 of 6 reviewers)

Reactions to this question were positive. One person pointed out the goal of a 2,000-2,500 lbs weight saving and fuel saving of 300,000 gallons. Another person noted that the project combines a new design approach with the use of aluminum for weight reduction leading to increased fuel efficiency. Another reviewer added that the project will result in an immediate improvement in vehicle mass reduction and accompanying fuel efficiency by reducing the ratio of miles traveled to gallons of fuel delivered. The final reviewer commented that this is a great example of the technology touching the road. As Phil Sklad of ORNL stated at the meeting, the benefits of weight savings cannot be realized unless the technology actually is deployed on the street. The result is a very innovative design that offers significant potential for other applications.

Question 2: Approach to performing the research and development (Written responses from 3 of 6 reviewers)

One person simply stated that the researchers have used good approaches, while another person felt that they have used an excellent comprehensive engineering approach. The last reviewer commented that the researchers have developed a very systematic approach that would be expected from an OEM in the business of keeping the shareholders happy. They liked the input provided by the end user and how that affects the form, fit, and functionality of the final design; if the customer does not like it because the users cannot use it then it becomes wasted innovation.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 2 of 6 reviewers)

One reviewer simply stated that the researchers have shown good progress. Another reviewer commented that this project has come from the drawing board to the weld shop to the formulation of a new Alcoa aluminum alloy for this particular application. They added that they feel the technical accomplishments are very obvious and again actual hardware has been welded, tested, revised, retested, etc.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 5 of 6 reviewers)

One reviewer felt that with this project, as with others, there is a question as to how the technology transfer will take place. They assume that the design activity will stay proprietary with the OEM. Another reviewer felt that there was very good interaction with Heil, but limited with other suppliers. Two reviewers noted the excellent use of focus group studies of potential customers. Another reviewer expanded on this, stating that the investigators did a marketing survey, and similar surveys should be used in other programs. The final reviewer commented that the design is the weight saving feature, but the question is how the design technology will be converted to the rest of the industry. This project represents a great weight saving activity, but it is an activity that perhaps needs to be funded wholly by the OEM where they retain the exclusive rights. Having the DOE fund this activity is perhaps inappropriate if the design methodology is going to be held close to the OEM breast pocket. This reviewer would like to have a direct line to Heil to discuss this design and how other OEMs could use the "chassis-less tanker and trailer design" in their designs.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 0 of 6 reviewers)

None of the reviewers offered any written comments on this aspect of the research.

Specific Strengths and Weaknesses (Written responses from 3 of 6 reviewers)

- Specific Strengths
  - Practical approach. Excellent communication with potential customers.
  - Utilized new alloys and analytical analysis to optimize design for light weight cost-effectively and to take the design to market.
- Specific Weaknesses
  - Did not mention what aluminum alloy was used.
  - Lack of economic analysis to show financial impact of various design options. Low impact on total fuel use of entire truck fleet. What are opportunities, if any, to migrate developments to other vocations?
  - Appears to be largely an engineering redesign effort rather than scientific research.
  - Unfortunately, based on the marketing survey it appears that the work is being re-directed to achieve less impact in the areas of aerodynamics. It seems that more time should be spend on obtaining additional customer input on methods to achieve driver satisfaction and benefits to the driver.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 1 of 6 reviewers)

- DOE should evaluate benefits of further funding.

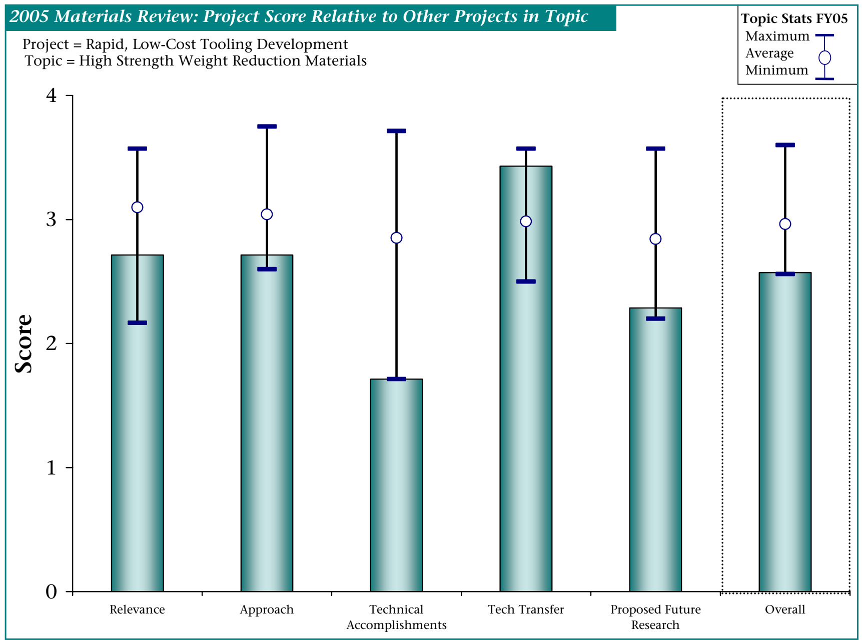
Question and Answer Session at Review

Q: Rogelio Sullivan – How much of the weight savings did you give back when you reintegrated the customer requested design elements, such as the redesigns of cabinets and piping?
A: Tumlin – About 500 pounds was placed back upon the trailer out of the 2000 pounds removed: most of the weight savings is achieved through the trailer structure. This weight savings may also be able to be recovered by using a thinner wall design. There are strength concerns, however. Some aerodynamic benefit was lost as well, but we are looking at redesigning conventional cabinets to improve aerodynamics.

Q: James Quinn – You indicated that you were using a new aluminum alloy; who is providing the alloy?
A: Tumlin – Alcoa is providing the aluminum alloys, and work is just starting here. We will use a flat plate 6005A alloy for much of the extrusions and framework. As for the other areas, the alloy is still undetermined at this time.

High Strength Weight Reduction Materials

Rapid, Low-Cost Tooling Development; Cliff Eberle of Oak Ridge National Laboratory



Brief Summary of Project

In this project, Oak Ridge is working to determine whether current tooling technology inhibits lightweight materials development and commercialization, and to develop a roadmap for tooling technology R&D and recommend a DOE course of action.

Question 1: Relevance to overall DOE Objectives (Written responses from 4 of 7 reviewers)

One reviewer commented that this project identifies a barrier for introducing new lightweight technology. Another reviewer noted that the development of roadmaps is always appreciated. Another person noted that the project goals represent potential cost saving to industries. The final reviewer commented that this work is highly critical in the use of polymer matrix composites and their introduction into low- and medium-volume vehicle manufacturers. This reviewer added that, as a representative from a low-low volume vehicle manufacturer, tooling is the number one issue preventing a more widespread use of polymer matrix composites.

Question 2: Approach to performing the research and development (Written responses from 5 of 7 reviewers)

Reactions to this question were positive in general. One reviewer felt that the approach with workshops is appropriate for this type of project. Another person agreed, stating that the benchmarking and workshops are an effective means of gathering information. One reviewer, however, wondered if the labs are the best organizations to conduct surveys. Another reviewer agreed that the workshops were a good approach that engaged tool manufacturers; however, the fragmented and diverse nature of the work makes it difficult for them adopt higher technology. The final reviewer had detailed comments. They noted that the researchers used a two-part workshop to get the user input that developed a very methodical understanding of what the real issues are in preventing the use of lightweight advanced materials technology as well as the energy used in the manufacture of tooling. The researchers showed that based on this in-depth evaluation, the "health" of the tooling industry became questionable. As with other industries, the U.S. is quickly losing tool manufacturers. The scourge of the "big three" in keeping payments from tooling companies, and driving the tool manufacturers in the ground for the lowest price is severely damaging our technology base, this reviewer said. The socioeconomics of the tooling industry and the adoption of new technology (or their willingness to adopt the technology) is essential to turning the tooling industry around.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 4 of 7 reviewers)

Reactions to this question varied widely. One reviewer felt that the presentation showed interesting results from the survey. Another person commented that the program is more of an information gathering activity to reveal the barriers. A third reviewer pointed out that the project only identified a new barrier. The final reviewer felt that this area can not really be rated considering the socioeconomic problems.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 3 of 7 reviewers)

One reviewer felt there was a broad range of players in the field involved. Another person commented that there was a significant amount of understanding gained and contact with tool manufacturers who are open to new tooling technologies have been made. The final reviewer suggested that this work should be given to the Center for Automotive Research at Ohio State University.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 4 of 7 reviewers)

One reviewer felt that the project needs a defined direction. Another person agreed, stating that it is not apparent from the presentation what the next steps will be, but the project did a good job of showing the barriers. One reviewer commented that to get a good insight in future research needs a roadmap is a good instrument. They added that it is a good thing that the follow-on work on the project will be forwarded to a more specialized organization. The final reviewer had detailed comments, stating that this project is important for our nation's health and well being. They added that the principal investigator has unearthed a major issue that the printed circuit board manufacturers, foundries, and forging specialists are dealing with in regards to the "big three" auto manufacturers. This reviewer said, "Our government bails them out and then they drive their supplier out of business."

Specific Strengths and Weaknesses (Written responses from 5 of 7 reviewers)

- Specific Strengths
  - Involvement of the OEMs and suppliers.
  - Benchmarking and workshops.
  - Sounds like it is starting over based on little if any information gathered thus far.
- Specific Weaknesses
  - This appears to be an economic issue that should be funded elsewhere. Once OEMs realize the problem exists, they will have to address or fall behind. It is in their best interest to address.
  - The project went in a direction outside the core competence of the researchers.
  - Lack of specific direction on future activities, although it appears that this is already known, just not revealed in the presentation.
  - No technical research; too costly and time consuming for the limited information gleaned thus far; no indication of what qualifies ORNL to formulate the Roadmap for low cost tools.
  - Primarily a financial analysis of the tool industry; not much in the way of research in this area at this point in time.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 3 of 7 reviewers)

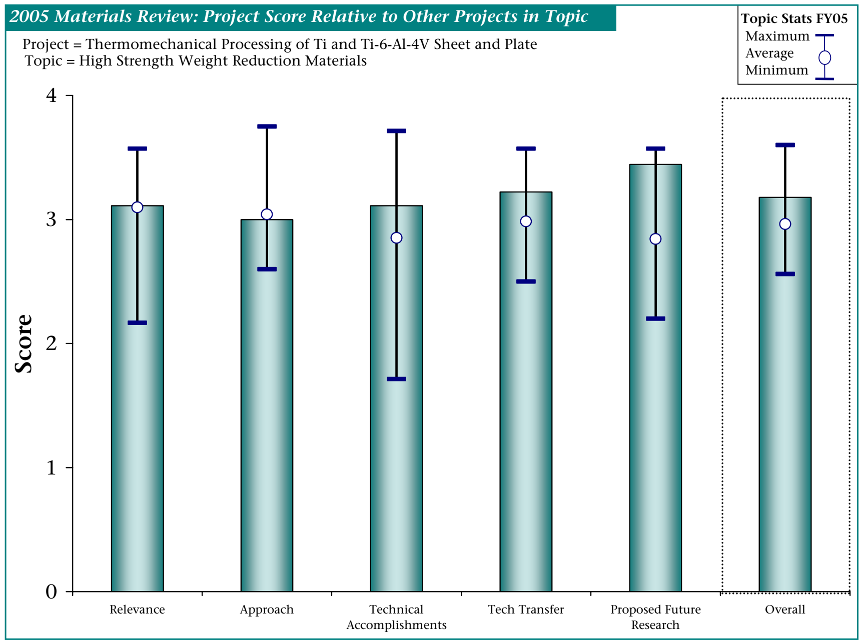
- The labs should be focusing on technical solutions to reduce cost.
- Start outlining plans to explore technology opportunities in advance of the program completion date.
- Enlist manufacturing organizations, such as the Society of Manufacturing Engineers or Tool and Die Maker associations to take lead responsibility for the roadmapping.

Question and Answer Session at Review

None.

High Strength Weight Reduction Materials

Thermomechanical Processing of Ti and Ti-6-Al-4V Sheet and Plate; Craig Blue of Oak Ridge National Laboratory



Brief Summary of Project

In this project, researchers are looking to provide weight reduction in heavy-duty vehicles such as Class 8 trucks through the utilization of titanium components developed from new low-cost titanium powders and processing technologies. In FY 2005, the team is focusing on production, chemical analysis, and mechanical testing of low cost titanium, Grade 2 and Ti-6Al-4V alloy, Grade 5 parts.

Question 1: Relevance to overall DOE Objectives (Written responses from 6 of 9 reviewers)

Several reviewers felt that this was a great initiative to reduce the cost of titanium through fabricating new low cost titanium powders is definitely a worthwhile endeavor with a 44 lbs (~40%) weight reduction. Another reviewer had detailed comments, stating that cost is still the primary barrier for implementation of titanium in transportation. They point out that if powders are $5 per pound and this is 50% of the cost with processing the remainder of the cost, then this project will not significantly advance titanium implementation. However, if titanium material costs are reduced, than this project has done a reasonable job of showing the potential component processing methods. Another reviewer was unclear of the impact on the work on fuel economy, and they questioned if cost will be an issue for this approach. The final reviewer felt that the project is too related to milestones and not enough to metrics.

Question 2: Approach to performing the research and development (Written responses from 6 of 9 reviewers)

Reactions were mixed to this question, and several questions were offered. One reviewer stated that the researchers used a structured approach and showed great capability. Another person commented that the project has shown concept feasibility of producing titanium components from sheet and extrusions produced from titanium powders, but questioned whether it would it be better for the program to focus on the most cost effective means of producing titanium components, i.e. extrusion rather than forging or sheet. One reviewer commented that from the delivered talk, one senses progress has been made but it could be improved if the correspondence with metrics were to be better illustrated. It was not clear to another reviewer why thermomechanical processing is an advantage over more conventional plate forming methods. Another person commented that the approach was not clear in terms of comparisons to other metals in terms of structure-property relations. The last person asked how the cost of this process compares to standard processing routes at this stage of the development.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 4 of 9 reviewers)

Reactions to this question were positive. One reviewer simply stated that the researchers have shown good promising results with the low cost titanium powder. Another stated that it appears that the processes used are technically feasible. It is now time to determine if they are commercially feasible. One person felt that the project shows good progress in obtaining a rough impression of two of the three processing methods. The last reviewer commented that getting the powder properties similar to wrought materials is impressive.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 6 of 9 reviewers)

Several reviewers noted the presence of industrial partner ITP as raw material supplier as well as the component manufacturer Boler. One reviewer questioned if the $5 per pound powder cost is a realistic target; if not, this reviewer wondered if the powder cost would kill the chances of commercialization, or if the unique forming characteristics would permit adequate price realization to offset the costs. They added that the project appears to be well on track for rapid commercialization and the collaboration with the Boler Company is very encouraging. One reviewer felt that the program does not appear ready for technology transfer. Further work shows promise.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 2 of 9 reviewers)

Reviewers had several questions regarding this aspect of the research. One person asked what Class 8 truck components are going to be tested. Another person felt that the proposed future research was vague and went too fast on the path forward. They commented that they would have rated this project higher if it had not gone too fast.

Specific Strengths and Weaknesses (Written responses from 8 of 9 reviewers)

- Specific Strengths
  - Good promise.
  - Partnership seems vertically integrated. Technical accomplishments demonstrated in "prototype" process rather than just small lab scale.
  - Good approach at looking at multiple production routes.
  - In trying to reach the powder titanium to the wrought titanium, great strides have been made.
  - The program has addressed the processing of titanium components which complements programs looking at addressing lower cost titanium materials.
  - Good demonstration of capability of available powder.
  - Replacing steel components by titanium ones is the strength of this program.
  - Developing application for a high-performance material generally considered "very expensive" by truck OEMs.
- Specific Weaknesses
  - What's the end cost and can it be mass produced?
  - Technology limitations not clearly identified. Again, what advantages does the process have over conventional plate manufacturing methods?
  - The price of titanium. Low volume of available titanium powder.
  - In relation to modeling however, quantitative structure-property relations in terms of densities need to be realized. They can use better methods to measure densities: computed tomography and optical microscopy can lead to more quantitative numbers.
  - Processing of titanium may be irrelevant as long as titanium materials are >$5 per pound and the involved processing of titanium from powder may still be too costly.
  - Doesn't seem to address cost of the titanium or processing it.
  - Not enough comparison metrics between steel and titanium components.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 5 of 9 reviewers)

- Clearly identify targeted categories of components suited for this technology.
- Definitely continue work but keep in mind what modelers would need.
- Once an understanding of the costs is obtained for the three processing methods, focus on the option that shows the most promise in terms of cost, component application and potential volume.
- My statements reflect the fact that, in my mind, the history of the program was not well explained. The fact that the Boler Company is already on board seems to indicate, however, that some of my comments may not be justified.
- Develop a value proposition for titanium alloys for heavy-duty trucks.

Question and Answer Session at Review

Q: Titanium must be economical to be feasible for use in production parts. Do you know what the approximate percent cost reduction is that can be achieved with this technology versus current procedures?

A: Craig Blue – In terms of roll compaction, we believe that a plate component could be reduced to \$4 material + \$2 processing per pound. Today material/processing cost varies from \$20 -50 per pound. To achieve this, the raw material costs are assumed to get down to \$4-\$5 per pound. Most of the new low-cost processes haven't progressed far enough along to do real testing.

Q: You indicated a 100% density: what is the resolution being used to obtain the density number (is 99% = 100% or is it 99.9%), and what measurement technique is being used?

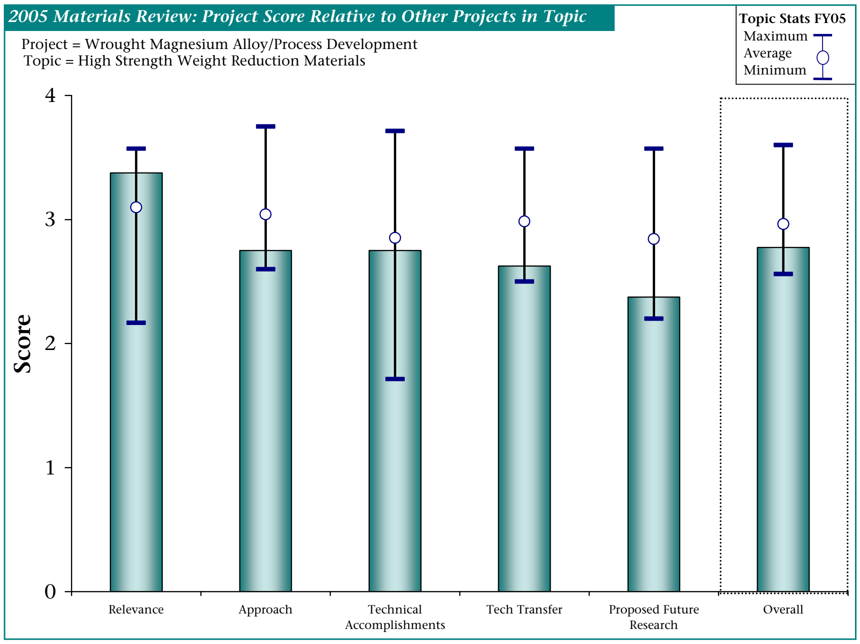
A: Craig Blue – Archimedes was used to determine the density as a bulk number. As this is an estimate, the density could also be considered equal to 99%.

Q: It was noted that a total of 44 pounds has been saved: what percent of the total weight of the part does this represent?

A: Craig Blue – The weight reduction represented is 40% without design changes to the part.

High Strength Weight Reduction Materials

Wrought Magnesium Alloy/Process Development; Joe Horton of Oak Ridge National Laboratory



Brief Summary of Project

This team is working to develop wrought magnesium alloys with better formability and lower costs by reducing processing steps. Their focus for FY 2005 is on infrared-assisted rolling in conjunction with current commercial process and a new twin roll cast process.

Question 1: Relevance to overall DOE Objectives (Written responses from 6 of 8 reviewers)

Reactions to this question were positive. One reviewer commented that this project has shown a great initiative to reduce cost. One reviewer noted that the use of magnesium can lead to significant weight reduction. Another person felt that the project provides weight savings commensurate to 21CTP goals and addresses cost issues associated with wrought magnesium. If the costs can approach pure metal costs, these efforts have the potential to add another lightweight manufacturing process to enhance lightweighting of vehicle structures. Another person commented that a result of a 63% reduction in weight for the same stiffness is dramatic. A reviewer noted the good fundamental understanding of material properties and their critical relationships to forming behavior. The last reviewer simply pointed out that the formability of magnesium sheet is key and important.

Question 2: Approach to performing the research and development (Written responses from 6 of 8 reviewers)

Reactions seemed to focus on the researchers needing to make this aspect of their project clearer to the reviewers. One person commented that there was a good mixture of addressing technical issues with emphasis on reducing costs; however, integration to other projects is unclear. Another person commented that it seems like a lot of aspects are being evaluated, but it was not clear how all the bits of info will come together to address. Another reviewer agreed, adding that the approach was very vague and hard to follow, so this reviewer did not get what they were really doing. One person commented that it is not clear how the project will enable lower cost sheet forming. Insufficient insight was given by the principal investigator in the current cost build up, noted this reviewer. One reviewer asked whether IR rolling is a commercially viable process. They felt that the work seemed to jump around, and that a more focused effort on a particular part with a partner would be great. The last reviewer agreed, adding that the selection of a target component to drive commercialization efforts would focus the development of processing around the critical parameters.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 4 of 8 reviewers)

One reviewer commented that the structure-property relations performed by Sean Agnew were excellent. Another person agreed, stating that a good insight was given in the metallurgical phenomena that are influencing formability. One reviewer noted that there was a good use of science, but correlation to commercial goals was not clearly demonstrated; i.e., how the technology relates to driving lower costs or ease of fabrication. The last reviewer commented that the work was focused on fundamental work. If this material is expected to play a larger role in wrought material applications, this type of work on how to process and heat treat the material is needed, and this information needs to be published.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 6 of 8 reviewers)

One reviewer simply stated that cooperation exists with primary suppliers. Another noted the close work with Magnesium Elektron. Another reviewer also noted the good collaboration with Magnesium Elektron, but felt that there was a need to include a component manufacturer as well. Another person commented that the work with Magnesium Elektron is a good start, but that an application partner would be better to pull the technology rather than trying to push it. Another reviewer asked whether Magnesium Elektron North America is the only magnesium company in the US, and thought that there may be another company in Salt Lake City, Utah. The final reviewer commented that although the work is technically sound, a relevant path to implementation does not seem to exist. They added that the technology can be developed and costs reduced, but prove out is necessary.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 5 of 8 reviewers)

One reviewer noted that studies on recrystallization are important, but just studying the kinetics is not enough however; kinematics and thermodynamics also need study. Another reviewer noted that the new facility (twin roll cast) will open new potential solutions for production of magnesium sheet. Another reviewer commented that the future work will be relevant once cost and performance objectives are met. Further verification on "real world" components would be beneficial. A reviewer was unclear on the project direction with the magnesium materials and what applications exist for this material. The final reviewer commented that the researchers need to include potential component supplier to understand and develop the technology per customer requirements. Is there a target component in mind?

Specific Strengths and Weaknesses (Written responses from 6 of 8 reviewers)

- Specific Strengths
  - Adequately addresses technology and cost issues.
  - Partnership with processor, fundamental materials characterization.
  - Partnering with Magnesium Elektron is a strength. An application partner will strengthen.
  - Very excellent structure-property relations for magnesium alloys which is lacking in the literature.
  - Well balanced and methodical study.
- Specific Weaknesses
  - Did not mention applications for this project.
  - This program would benefit from a plan of implementation or at least manufacture of a production intent component. This would afford a direct comparison to current wrought magnesium processes and resulting performance validation and cost comparisons.
  - Lack of target component and supplier.
  - $4.5/lb from processing. Hard numbers for cost reduction will give this work more weight.
  - The presentation was not clear in some areas: modeling, temperature (F or C)?
  - World wide available knowledge on wrought magnesium is not explored fully.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 3 of 8 reviewers)

- Demonstrate the technology on a heavy truck component.
- Select a target component to drive process variables based on technical characteristics.
- Incorporate a cost model for forecasted cost reductions once commercial type parts are formed.

Question and Answer Session at Review

Q: Relative to comparing the experimental calculation of slip rate to the model – which model was being used?
A: Joe Horton – I would have to consult the collaborators working on the model to find out. A lot of detail is required to develop these models.

Propulsion system materials are an enabling technology for fuel-efficient heavy-vehicle truck engines. The Heavy Vehicle Propulsion Materials Project is organized around the following technology issues: fuel systems; exhaust aftertreatment; air handling, hot section, and structural components; and standards.

Below is a summary of average scores for 2005 for the fourteen projects in this category, along with the average, minimum, and maximum score for all projects in this report. The highest score in this category for each question is highlighted. Scores are on a basis of 1 to 4, with 4 being the highest.

Summary of Scores for Projects in this Section

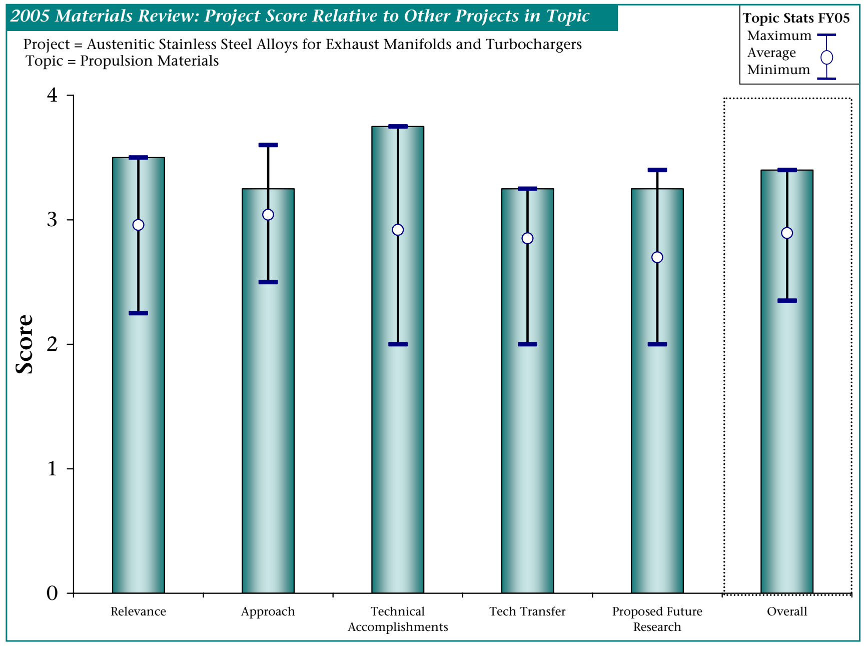
Page Number for Project Summary	Research Project Title	Q1 Relevance Score	Q2 Approach Score	Q3 Technical Accomplish-ments Score	Q4 Tech Transfer Score	Q5 Future Research Score	Overall Average Score
52	*Austenitic Stainless Steel Alloys for Exhaust Manifolds and Turbochargers;* Michael Pollard (Caterpillar Inc), Phil Maziasz (Oak Ridge National Laboratory)	3.50	3.25	3.75	3.25	3.25	3.40
54	*Catalyst Characterization;* Roger England (Cummins Inc.), Thomas Watkins (Oak Ridge National Laboratory)	3.14	3.29	3.00	3.14	2.57	3.03
56	*Catalyst via First Principles;* Chaitanya Narula (Oak Ridge National Laboratory)	2.80	2.80	2.20	2.60	2.20	2.52
58	*Characterization of Catalyst Microstructures and Deactivation Mechanisms;* Larry Allard (Oak Ridge National Laboratory)	2.80	2.60	2.00	2.80	3.40	2.72
60	*Durability of Diesel Engine Components;* Peter Blau (Oak Ridge National Laboratory)	3.17	3.33	3.33	3.17	2.50	3.10
63	*Durability of Particulate Filters;* Tom Yonushonis (Cummins Inc.), Edgar Lara-Curzio (Oak Ridge National Laboratory)	3.20	3.60	3.40	3.20	3.20	3.32
65	*IEA Annex on Materials for Transportation Applications;* Andy Wereszczak & Mattison Ferber (Oak Ridge National Laboratory)	3.00	2.75	2.25	2.75	2.50	2.65
67	*Integrated Surface Modification;* Stephen Hsu (NIST)	3.40	3.20	3.20	2.60	3.00	3.08
69	*Lightweight Valve Train Materials;* Jeremy Trethewey (Caterpillar Inc), J.G. Sun (Argonne National Laboratory), H.T. Lin (Oak Ridge National Laboratory)	3.00	3.60	3.20	2.80	3.40	3.20
71	*Materials for Exhaust Aftertreatment;* Herbert DaCosta & Ron Silver (Caterpillar Inc.)	3.20	2.80	3.20	2.00	2.80	2.80
73	*Mechanical Behavior of Ceramic Materials;* Andy Wereszczak (Oak Ridge National Laboratory)	2.50	2.50	2.50	2.75	2.25	2.50
75	*Nanocrystalline Materials by Machining;* Srinivasen Chandresekar (Purdue University)	2.25	2.50	2.75	2.25	2.00	2.35
77	*NOx Sensor Development;* Tim Armstrong (Oak Ridge National Laboratory)	3.00	3.00	3.17	3.00	2.50	2.93
79	*Titanium Engine Components;* Paul Becker (University of Tennessee)	2.40	3.00	2.60	2.80	2.60	2.68
	Average Score for This Category	**2.96**	**3.04**	**2.92**	**2.85**	**2.70**	**2.89**

Overall Program Scores

	Q1 Relevance Score	Q2 Approach Score	Q3 Technical Accomplish-ments Score	Q4 Tech Transfer Score	Q5 Future Research Score	Overall Average
Overall Program Average	3.05	3.04	2.88	2.93	2.79	2.94
Overall Program Maximum	3.57	3.75	3.75	3.57	3.57	3.60
Overall Program Minimum	2.17	2.50	1.71	2.00	2.00	2.35

Heavy Vehicle Propulsion Materials

Austenitic Stainless Steel Alloys for Exhaust Manifolds and Turbochargers; Michael Pollard of Caterpillar Inc and Phil Maziasz of Oak Ridge National Laboratory



Brief Summary of Project

This ORNL/Caterpillar CRADA has been focused on commercialization of the new CF8C-Plus cast austenitic stainless steel to replace SiMo cast iron for advanced diesel exhaust manifolds and turbochargers. Caterpillar is focused on upgrading turbochargers from cast iron to cast stainless. Direct comparison of CF8C-Plus (MetalTek) and KN2 (Diado) stainless steels is in progress at ORNL to support turbo supplier needs.

Question 1: Relevance to overall DOE Objectives (Written responses from 3 of 4 reviewers)

One reviewer commented that this is a program that goes far beyond DOE: the present project being one application among many. Others agreed, adding that this is a well focused effort and well managed. They noted the 3% efficiency improvement in fuel economy with a 90 degree increase in exhaust gas temperature, and pointed out the clearly defined benefits should the material prove commercially viable in terms of cost vs. performance.

Question 2: Approach to performing the research and development (Written responses from 2 of 4 reviewers)

One reviewer commented that the approach compared the material to commercially used materials in diesel engine exhaust as well as gas turbine systems. Another noted that the cast trial steel was used for testing and material property characterization.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 2 of 4 reviewers)

One reviewer noted that the researchers showed improved creep resistance, tensile, and TMF strength. Another person commented that the researchers used creep tests and creep behavior modeling, performed tensile and ductility exercises, and looked at thermal cycling effects to prove the material had better performance over commercial practices, which resulted in well-characterized results.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 3 of 4 reviewers)

Two reviewers noted that three foundries now have trial licenses for the process and are capable of producing this material. This shows quick technology transfer is possible in the short term. Another reviewer stated that they would have liked to see much more here in terms of transfer.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 3 of 4 reviewers)

One reviewer commented that the future plans hold good promise for high temperature applications. Another commented that the future of centering on fatigue issues is well-characterized. The final reviewer cautioned that the relevance of proposed future research was underestimated.

Specific Strengths and Weaknesses (Written responses from 2 of 4 reviewers)

- Specific Strengths
  - Excellent material development work.
  - Excellent program, deserving to be even more forward looking.
- Specific Weaknesses
  - The weaknesses appear to be in the dissemination of the results and in establishing bridges for other applications.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 1 of 4 reviewers)

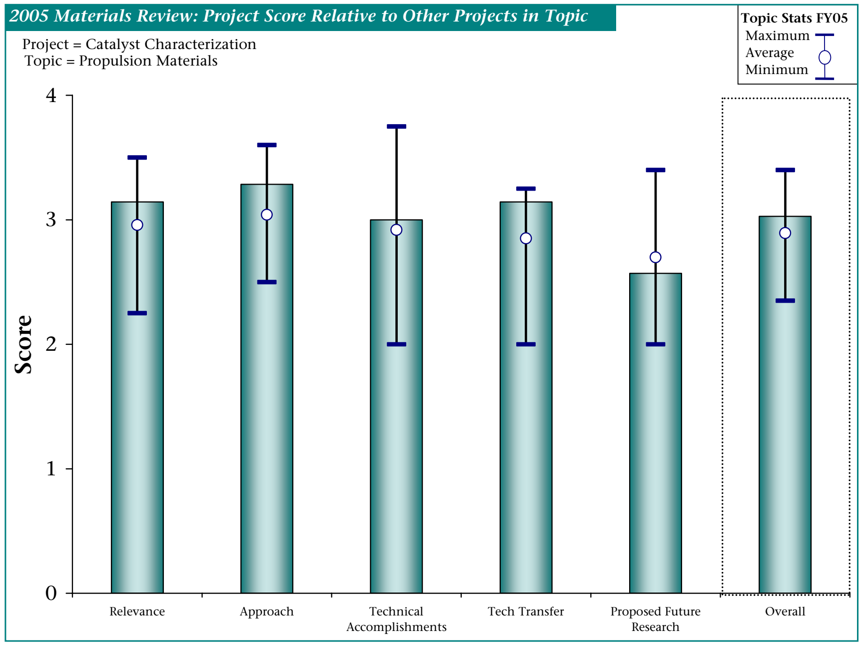
- Development and application of new materials are very important for our future. Keep it up!

Question and Answer Session at Review

Q: Dr. James Eberhardt – Is there any chromium in the formulation?
A: Pollard – Yes, there is between 18 and 20% chromium.

Q: Dr. James Eberhardt – You indicated that this formulation is being used in a petroleum drilling application, what about stress corrosion cracking?
A: Phil Maziasz – Geological oil extraction of shale oil and tar sands are very high temperature procedures with exposure to oxidation and sulfation. We haven't done a stress analysis on this application but I believe the material should behave just about the same as in an engine application. In addition, manganese was also added to the formulation to give the metal good liquid metal behavior and to improve casting dramatically. This permits the casting of more difficult shapes.

Catalyst Characterization; Roger England of Cummins Inc. and Thomas Watkins of Oak Ridge National Laboratory



<u>Brief Summary of Project</u>

This team of researchers is developing tools for state of the art characterization on diesel catalysts, both from reactor and engine testing, allowing validation of testing techniques. Their FY 2005 focus is on measurement & characterization of the surface features of diesel catalysts, including correlating these attributes directly to fuel economy measurements.

<u>Question 1: Relevance to overall DOE Objectives (Written responses from 3 of 7 reviewers)</u>

Reactions to this question were positive. One reviewer agreed that the project deals with an important enabling technology. Another reviewer said that in general, this effort seems to address practical in-service issues with real world NOx catalysts, but has failed to provide much in the way of data or conclusions; the data which the presenter claimed was proprietary. The final reviewer noted that the project addresses emission compliance and the effects on fuel economy. They added that the project is relatively open-ended, but time is what drives the work. The presentation did not delineate the direct technical benefits of the work being done and the results are presented without assessment of the value of the data towards DOE goals.

<u>Question 2: Approach to performing the research and development (Written responses from 4 of 7 reviewers)</u>

Reactions were positive in general, with suggestions of further definition of the work plan. One reviewer commented that the approach seems very good; specifically, evaluating real world catalyst behavior under in-service like effects in order to understand aging and also fundamentals such as kinetics. Another reviewer simply stated that the researchers have conducted a thorough study. One person commented that basic materials studies can provide a good general understanding of the fundamental mechanisms if correlated to actual data, but that the researchers need to show an overview of the project plan to demonstrate the path from materials characterization to engine validation. The final reviewer stated that the approach included a survey of what materials are available and the result will make a determination over a comprehensive survey. They reinforced that the project is not tightly defined on direction but the driving force is the available time to do the work.

<u>Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 5 of 7 reviewers)</u>

Reactions to this question were mixed. One reviewer felt that the researcher showed good results on microstructural analysis. Another commented that considering the time constraints, a parallel approach between tool development and correlation methodology to engine emissions would be beneficial. Other reviewers were more critical. One reviewer stated that they would like to see more realistic catalysts. Another person noted that the presenter claimed data was proprietary so it was difficult to assess accomplishments and progress. The final reviewer acknowledged that the work examined platinum mechanisms of particle and crystallite size, and sulfation issues along with data generation, but technical progress towards DOE goals is not clearly presented.

<u>Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 6 of 7 reviewers)</u>

Reactions to this question were positive. Several reviewers commented on the good interaction between Cummins and ORNL and the good exchange of experimental data among Johnson-Matthey, Cummins, and ORNL. Another reviewer added that the involvement of catalyst supplier Johnson-Matthey is important. However, one reviewer commented that the progression to engines is not readily apparent, while another questioned what Johnson-Matthey's role will be.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 6 of 7 reviewers)

Reactions to this question were mixed. One person felt that the project is heading in the right direction. Others felt that this area could be improved. One reviewer felt that Johnson-Matthey needs to play a larger role and that this needs to be communicated. One reviewer commented that the future plans and endpoints need better definition. Another reviewer agreed, adding that the presenter seemed to hold back details concerning future efforts and what they were learning in this project. One person suggested that a timeline to emissions targets should be laid out more thoroughly. The final reviewer had detailed comments, stating that ORNL High Temperature Materials Laboratory capabilities should be utilized. Time and EPA regulations are driving the program and there was no mention on what direction in which the work will concentrate, but a shotgun approach is implied. It is a question of how much of the experimental results will be available to competitors of Johnson-Matthey and Cummins. Due to EPA regulations coming due in a few years, it was not clear to this reviewer when the project would declare completion.

Specific Strengths and Weaknesses (Written responses from 4 of 7 reviewers)

- Specific Strengths
  - Strong collaboration among ORNL, OEM, and supplier.
  - Fundamental studies with materials.
  - Good fundamental work on the tools.
  - Good combination engine manufacturer/catalyst supplier effort.
- Specific Weaknesses
  - Ill-defined objective/end point.
  - Lacks parallel effort in component validation.
  - Platinum on alumina is a model catalyst and as such it is difficult to make realistic conclusions without accounting for the stabilizers and other "stuff" in the catalyst washcoat "soup."
  - Too secretive with data and future efforts.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 1 of 7 reviewers)

- More strongly communicated goals.

Question and Answer Session at Review

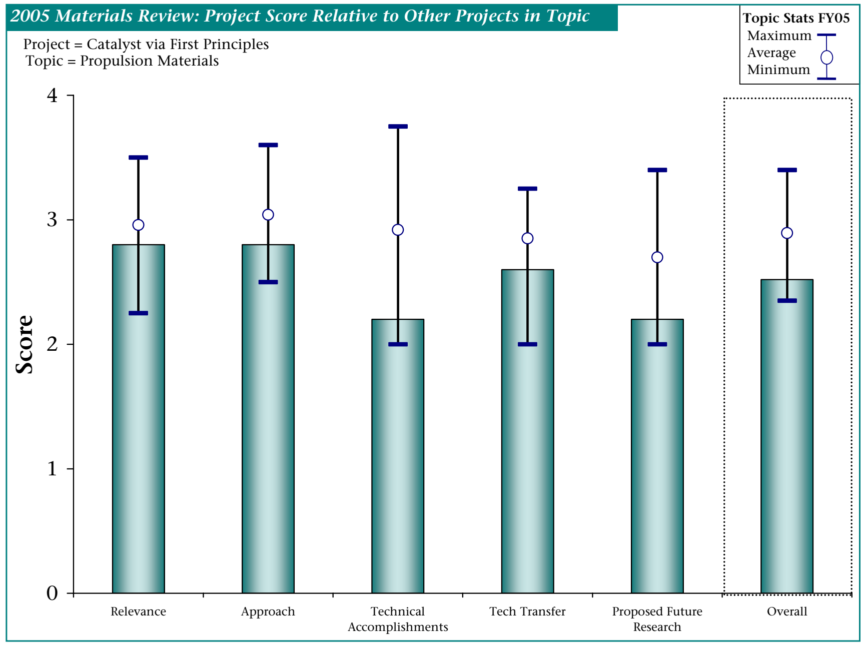
Q: Ed Ungar – It appears that Cummins and Caterpillar are still working on the fundamentals of aftertreatment. When do you need to get to a point where you are able to make a decision on the approach you will use to meet the 2010 emission standards?
A: England – That point is sooner than the engine companies would like. Companies have specific paths defined for engines to reach the standards, but we don't have a lot experience on working with catalysts and path to achieve the 2010 emission targets is still unknown. We will have to get there, however.

Q: Craig Haberger – This project represents good fundamentals, but are you looking at any more realistic catalysts rather than platinum on aluminum now that Johnson Matthey is involved?
A: We are working on developing the tools needed to understand the catalysts a little better. As we more forward, we will have the information to assist everyone in achieving the standards, and we will have specific information to help Cummins directly. Sharing the fundamental information gets everyone closer to the goal.

Q: Rogelio Sullivan – This is a useful tool, but appears to be an open-ended study. Is there a fixed end point of this project?
A: England – We believe that we need 2-3 years of more work to exhaust the capabilities of the national laboratories to understand the capabilities of these catalysts.

Heavy Vehicle Propulsion Materials

Catalyst via First Principles; Chaitanya Narula of Oak Ridge National Laboratory



Brief Summary of Project

The team's goal is to demonstrate that "computationally complex but experimentally simple" systems can be examined by both first principle theoretical models and experimental work to forecast improvements to obtain optimum catalyst systems. Our focus has been on the computational and experimental study of supported Pt and Re clusters. The theoretical efforts, which are based on the Density Functional Theory (DFT), have so far been focused on the oxidation behavior of Pt nanoclusters. The experimental studies have been focused on synthesis and characterization of Pt and Re nanocatalyst systems.

Question 1: Relevance to overall DOE Objectives (Written responses from 2 of 5 reviewers)

Reactions were mixed to this question. One reviewer commented that not only are the researchers developing an understanding of the catalyst system through modeling, but they are also aiming toward improving catalyst performance. Another person commented that this is a very fundamental project studying the molecular level behavior of catalysts, but it does not seem to have a practical end point goal. It is very unclear what contribution this effort will make in designing future catalysts and thus it is supporting 21CTP indirectly by enabling aftertreatment systems.

Question 2: Approach to performing the research and development (Written responses from 2 of 5 reviewers)

Reactions to this question were mixed, but were in general critical of the approach. One reviewer felt that the researchers used a good combination of modeling and fundamental experimental results to establish protocols, but they lack the linkage with suppliers to make the protocols have any real value. Another reviewer commented that the approach does not seem to include any link to the actual development processes of future NOx aftertreatment devices, and suggested that the principal investigator should make it clear where is project is heading and what its practical application and limitations might be based on the employed experimental approach.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 2 of 5 reviewers)

One reviewer noted that the researchers have demonstrated the difference between bulk material behavior and atomic clusters. The last reviewer commented that right now this project appears to be a fundamental exploration into the molecular structure and the limited chemistry behavior of catalyst surface locations that does not seem to yield any type of practical contribution to DOE 21CTP goals.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 3 of 5 reviewers)

Two reviewers commented that this project includes interaction from national labs and industry, so the collaboration appears to be adequate. However, another reviewer questioned why the researchers are not collaborating with a catalyst company and an engine OEM.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 2 of 5 reviewers)

Reactions to this question focused on the need for clarification of the goals and the path to achieve the goals. The first reviewer commented that the researchers need a clearer implementation path, adding that they have a good scientific foundation, but it is not clear how knowledge will be transferred in a reasonable time to commercialize. The second reviewer commented that the future work seems to focus on fundamental molecular level issues that do not link back to DOE 21CTP goals; the principal investigator needs to make the overall goal of this effort clear and how the associated project analysis contributes to this goal.

Specific Strengths and Weaknesses (Written responses from 2 of 5 reviewers)

- Specific Strengths
  - Interesting work.
  - Modeling capabilities and fundamental materials characterization.
- Specific Weaknesses
  - Collaboration with industrial partners is lacking.
  - Lack of focus toward the 21CTP goals.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 1 of 5 reviewers)

- Strongly recommend that the principal investigator makes it clear how the various work tasks are practically aimed at improving future catalyst formulations and/or 21CTP goals.

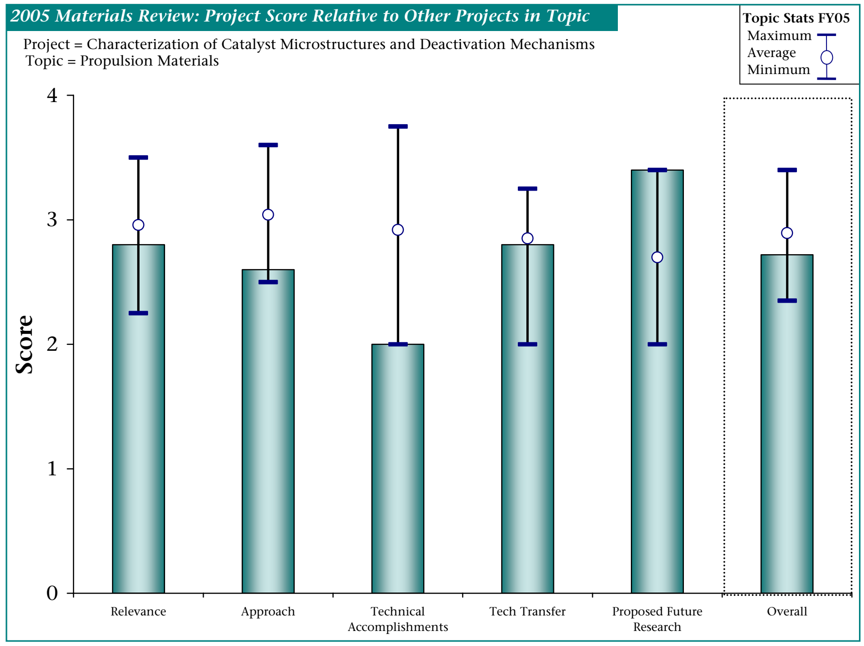
Question and Answer Session at Review

Q: Paul Becker – In terms of chemistry, the platinum atom has all of its valence shells filled and can't oxidize, but it appears to do so. How?
A: At this level, it doesn't appear to be due to metallic bonding: unsure of how this occurs.

Q: Craig Haberger – Have you thought about the effect of the electron beam on the structure and its effect on transients?
A: Narula – Yes but we used software to understand the reaction.

Q: Rogelio Sullivan – The endpoint of the project appears to be a protocol for catalyst development. Can this protocol be used for specific catalysts?
A: Narula – Concepts are being understood, we still need to understand if a material is oxide or metal and how it will react, this is still being investigated.

Q: Rogelio Sullivan – In your information, you indicated that funding for this project was $0 for FY2004 and FY2005. Is this correct?
A: Narula – No this was an error, the correct numbers were in an earlier presentation slide.



Brief Summary of Project

The team's goal in this project is to utilize ultra-high resolution imaging and spectroscopy capabilities of the ORNL aberration-corrected electron microscope (ACEM) to characterize "real" and "model" diesel and automotive catalyst systems to better understand mechanisms controlling aging and poisoning behavior of exhaust emission reduction catalyst materials. The 2005 focus is to model metal cluster systems of known cluster size on oxide supports to develop capability to reliably characterize our experimental and real catalysts at sub-Ångstrom resolutions, and to use the ACEM to characterize a series of real-world catalysts (supplied by Ford Research Lab) to determine aging behavior mechanisms.

Question 1: Relevance to overall DOE Objectives (Written responses from 4 of 5 reviewers)

Two reviewers noted that the presentation showed a great tool for fine scale analysis and catalyst development. Another reviewer noted that the project goal is oriented towards an emissions-complaint engine system, and as a result, the project is meant to develop an understanding of the mechanisms at the sub-Angstrom imaging range and understanding at the atomic level the mechanisms of platinum. The last reviewer noted that this project includes incredible experimental techniques in assessing catalyst material surface atomic structure under both green and aged conditions. Nevertheless, it is unclear if this effort will ever lead to a practical contribution in future catalyst development, but should be pursued due to the new information that will be developed in lieu of the new experimental techniques.

Question 2: Approach to performing the research and development (Written responses from 2 of 5 reviewers)

One reviewer noted that the researchers have developed an aberration-corrected electron microscope system at the ORNL High Temperature Materials Laboratory and will examine platinum mechanisms. Another person commented that the approach is practically not clear, because collectively the community seems to have a handle on how to use the new experimental tool employed in this effort. Therefore, it is unfair to assess the principal investigator's approach, in this reviewer's opinion.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 5 of 5 reviewers)

Reactions were mixed, but were generally positive. Two reviewers simply stated that the researchers have shown very impressive capability regarding methods to characterize materials by high resolution electron microscopy. One person, however, felt that the group should move faster in getting fully operational. Another reviewer acknowledged that the aberration-corrected electron microscope was purchased, delivered and installed, but it is too early to determine if work will assist DOE goals. The final reviewer declined to rate the project, stating that the new experimental technique has just gone through a development effort and has not been applied to catalyst yet, but that data/analysis should begin next fall.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 3 of 5 reviewers)

Two reviewers noted that this project has a good combination of national lab and industry effort including engine companies and catalyst companies. Another reviewer felt that at this point, commercial involvement is not required.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 3 of 5 reviewers)

Reactions to this question were mixed. One reviewer commented that catalyst aging is a good goal. Another reviewer commented that the relevance to future platinum work can be dramatic if positive results are yielded from a functional aberration-corrected electron microscope. However, as time marches on EPA regulations will beat out the driving urgency this project, hence, reducing the importance of this work. The last reviewer commented that it is unknown if practical information for catalyst design will be generated during this effort; with this premise the proposed approach of analyzing catalyst samples is a good future approach that is difficult to criticize until more is learned concerning the practical usefulness of this experimental technique.

Specific Strengths and Weaknesses (Written responses from 4 of 5 reviewers)

- Specific Strengths
  - Great capability.
  - Value of examining the mechanisms of platinum at the atomic level.
  - Great experimental facility at ORNL.
  - Great tools. Need to work to bring catalyst companies into the laboratory to evaluate fully formulated systems to determine the capability of the instrument in the real world. Work with the Umicore catalyst is an excellent example.
- Specific Weaknesses
  - Time enough to resolve the problems of the aberration-corrected electron microscope to be of an impact in meeting EPA regulations.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 0 of 5 reviewers)

- None noted by reviewers.

Question and Answer Session at Review

Q: Dr. James Eberhardt – Can you see high molecular weight (polymer) molecules that can be adsorbed or physisorbed in-situ? Can these molecules move around, and can we see if they break down?

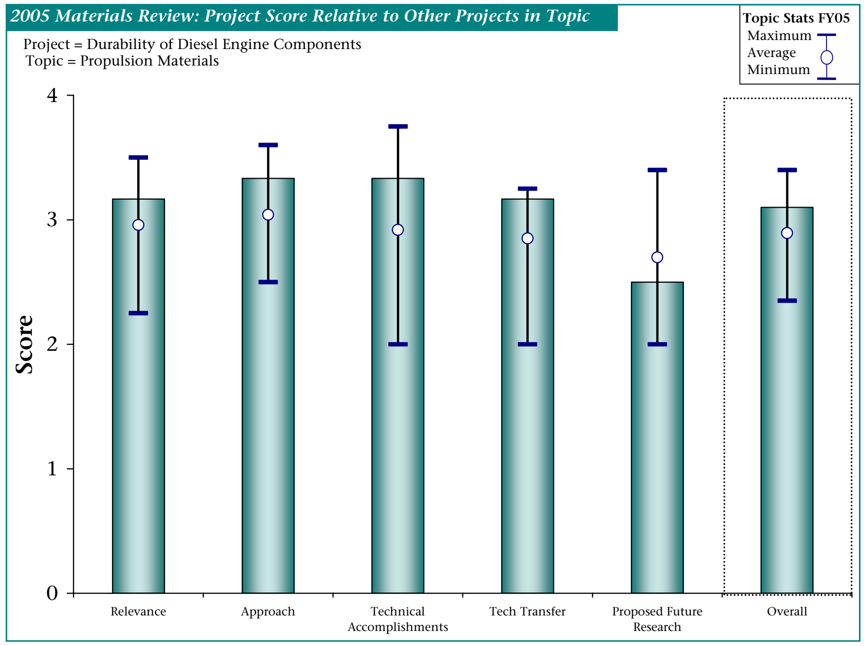
A: Allard – It is necessary to have support substrates with atoms of lower atomic number than the atoms you are trying to view.

Heavy Vehicle Propulsion Materials

Durability of Diesel Engine Components; Peter Blau of Oak Ridge National Laboratory

Brief Summary of Project

The objectives of this project are to quantify, model, and prevent surface damage in diesel engine components like EGR valve actuators and fuel injector plungers that must operate in low-sulfur fuels. The focus for the current work is to test the durability of advanced materials and surface treatments, and develop a multi-stage model for the initiation and propagation of scuffing in fuel injectors.



Question 1: Relevance to overall DOE Objectives (Written responses from 5 of 6 reviewers)

One reviewer commented that this project has aspects that may help in reducing friction in certain engine subsystem components, but overall probably will have minimal impact on overall vehicle fuel consumption. However, the main benefit of this program is in addressing future potential wear problem areas with future engine subsystem components (including injector needles) that may occur due to changes in both future fuel and lubricant formulation standards. Another reviewer added that friction reduction is very important to increasing efficiency. One reviewer acknowledged that the researcher is developing new test methods for scuffing. One person commented that the improvements to wear resistance are intuitive; it would be beneficial to see exemplary case histories; e.g., wear/friction improved X% resulted in BSFC saving of Y%. The last reviewer commented that the ability to improve fuel economy and emissions is directly tied to the capability of the fuel system. They added that cam rollers or cam-roller in common rail fuel systems should be considered.

Question 2: Approach to performing the research and development (Written responses from 4 of 6 reviewers)

Comments were positive to this question. One person commented that the researcher has used excellent test methods that were selected based on real application issues; however, they wondered if the transition maps/models are material-dependent. They added that it would be useful to have generic models for families of material pairs. Another simply stated that good experimental techniques were used. One person commented that the researchers have used an excellent fundamental approach toward studying tribology issues with certain engine subsystem components. The final reviewer noted that the researcher is developing wear test methods and modeling.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 3 of 6 reviewers)

One reviewer noted that the project has developed a model to predict onset of scuffing. Another stated that they feel this is interesting work on titanium. The final reviewer felt that the researchers have shown very good progress in developing techniques to address the assessment of injector needle wear and EGR valve bushing wear under engine-like boundary conditions. Additionally, the principal investigator discovered a potential thin film coating that may enable the use of titanium for certain high-wear engine components such as bearings. But this project probably will not contribute toward reducing overall vehicle fuel consumption, in this reviewer's opinion.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 4 of 6 reviewers)

Comments to this question were positive in general. One reviewer noted the researchers worked with diesel engine engineers and suppliers, while another person deemed the interaction with the heavy-duty engine manufacturers excellent. Another person agreed that good collaboration with engine OEMs on current field issues was shown, but some follow-up is needed to verify the improvements in terms of engine efficiency, fuel economy, emissions, etc. The last reviewer felt that more extensive collaboration to bring these technologies to fruition would be great.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 5 of 6 reviewers)

Two reviewers noted that work on valve train materials is a good next step. One reviewer suggested that the researchers need to clearly identify and partner with industry to develop a commercialization path; i.e., identify target components, material pairs, and environmental conditions to define technical requirements. This work enables the wear models and bench testing to be correlated to real-world applications. Another person noted that the project will turn its focus to other potential wear problem areas in diesel engines which is a reasonable approach for pushing the current R&D to address other real world tribology issues. The last reviewer felt there are possibly more critical areas than valve train for future work; perhaps better to look into high-pressure common rail systems and the cam loading which may become critical in future engines.

Specific Strengths and Weaknesses (Written responses from 5 of 6 reviewers)

- Specific Strengths
  - Developed unique test methods for specific applications.
  - Technical capabilities and fundamental understanding of wear behavior. Broad spectrum of material pairs. Wear models. Some ties to actual OEM issues. "Breakthrough" in understanding effects of processing of titanium on wear life and lubricant interactions.
  - Great minds at ORNL.
  - Excellent experimental capability.
  - Great experience in the tribology area applied to develop tools and information.
- Specific Weaknesses
  - Correlation of wear tests & models to real-world life prediction. Generic nature of wear models is not clear; i.e. material-pair specific?
  - Needs more collaboration and interaction with industry.
  - None that are obvious.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 3 of 6 reviewers)

- Partner with industry to correlate models/testing to actual components in real environments.
- None. But as a side note, Jet-A is not a low sulfur fuel in general but is a low lubricity thus making it a good test fuel candidate for injector wear experiments as discussed by the principal investigator.
- Cam rollers or cam-roller in common rail fuel systems should be considered   Also contact fatigue is critical as loads increase.

Question and Answer Session at Review

Q: John Grassi – At what temperature is the thermal oxide produced?
A: Blau – The treatment temperature must be between 550°C and 750°C. For this study, we treated at 600°C.

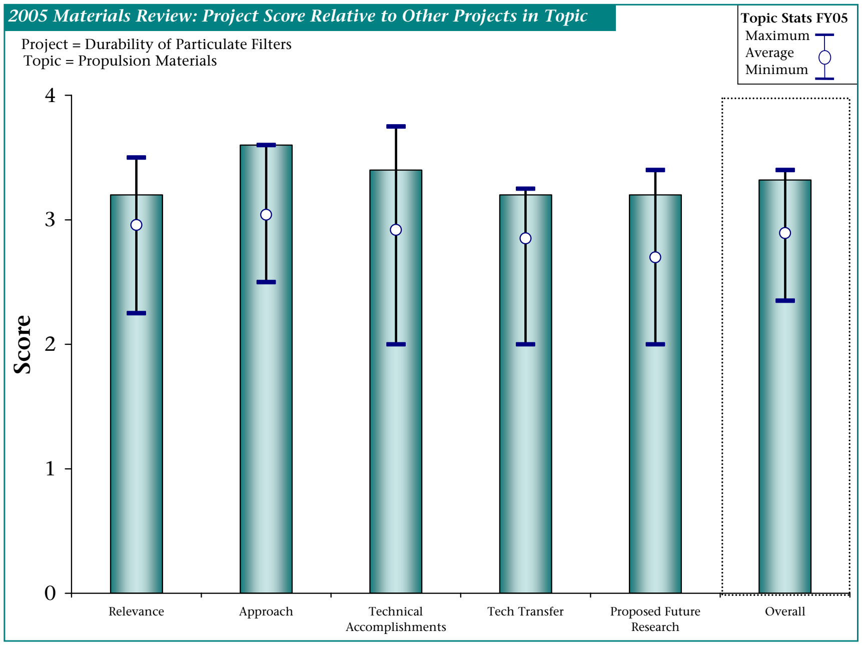
Q: John Grassi – How do you evaluate the progression of the titanium oxide film?
A: Blau – It progresses in three layers, a nitrogen rich layer in the middle, an oxide layer on top, and a titanium-oxide layer on bottom. The wear of this film has been demonstrated at 20 to 50 times better than cast iron.

Q: Phil Maziasz – In this film, the oxide layer is on top, with a nitride layer underneath. Have you considered putting the nitride layer on top?
A: Blau – Preliminary work was done on non-lubricated systems; our work here is based on lubricated systems. I agree that it is worthwhile pursuing if the opportunity presents itself.

Q: Paul Becker – If this friction reduction approach is to make it into a cylinder, do you know if this process will renew itself or does it eventually wear through the coating to the titanium?

A: Blau – Given the careful arrangement of the engine operating system, various lubricant formulations have been developed in the past for other operations that could self-renew the coatings so I believe through chemistry there is a way to develop a lubricant that will permit the coating to self renew.

Durability of Particulate Filters; Tom Yonushonis of Cummins Inc. and Edgar Lara-Curzio of Oak Ridge National Laboratory



Brief Summary of Project

Minimizing fuel consumption required for regeneration of particulate filters by determining the effect of regeneration imposed thermal stresses on ceramic filter life is the aim of this project. For FY 2005, the team is working to understand the critical material properties for life prediction and determining the stresses induced in porous cellular ceramics during operation.

Question 1: Relevance to overall DOE Objectives (Written responses from 5 of 5 reviewers)

One reviewer stated that the researchers have a good tool for optimization, while another noted that filters are essential to meet particulate limits. One person commented that the relevance of the project is in emissions compliance and durability of emissions devices and in particular diesel particulate filters. They added that the project has well outlined and focused goals; the intended benefits are clear and well defined against DOE goals. Another person acknowledged that life prediction and improvement is critical, but it was not clear to them how this relates to fuel economy. The belief was that the researcher was referring to a combustion strategy which maintains lower thermal loads to avoid cracking. The final reviewer commented that this project is focusing on the development of a methodology to predict particulate filter reliability and durability as related to a given duty cycle which indirectly supports the development of future aftertreatment systems for future heavy-duty vehicles. The reviewer added that the successful demonstration of this strategy should help to aid designers in optimizing engine aftertreatment systems.

Question 2: Approach to performing the research and development (Written responses from 4 of 5 reviewers)

Reactions were positive in general, but several questions were raised. One reviewer felt that the researchers have used a good combination of analysis of particulate filter materials and experimental effort to formulate a strategy for developing catalyzed diesel particulate filter models for reliability and durability. Another person noted that the project examines aging issues on diesel particulate filter devices including stresses, strains, and fatigue issues. They add that the researchers have used a sound and well thought out method of analysis in their well-covered approach. One of the reviewers asked whether the testing includes a combination of effects from temperature excursions and diesel exhaust constituents on ceramic life; thermal gradients as well as thermal cycling would have significant effects on such large structures. The last reviewer felt that this work is interesting, and wondered if Corning has seen this and what they think of it.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 4 of 5 reviewers)

Reactions were mostly positive. One reviewer commented that the environmental, thermal, and strength testing has been performed and that modeling was used to predict material performance as related to emissions. Others commented that there was a good match between finite element modeling and calculation, and that the project has a good start at measuring properties and establishing predictive models. The final comment was that the developed catalyzed diesel particulate filter reliability/durability methodology is not proven yet but shows promise based on benchtop testing of materials. Future experimental work on actual catalyzed diesel particulate filters should further improve the methodology development.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 4 of 5 reviewers)

Comments were favorable about the good interaction between the principal investigator, national labs, catalyst suppliers, and universities. One reviewer had more specific comments that modeling of diesel particulate filter materials will directly assist the entire industry in meeting emissions; however coordination seems to be limited to Cummins and Cummins suppliers.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 2 of 5 reviewers)

One reviewer felt that the researchers had a good recognition and identification of problems in environmental, strength, fatigue, and aging. Another reviewer was less sure, and felt that it was not clear how the researchers intend to leap from measurements and models on single cell structure to full-scale filters.

Specific Strengths and Weaknesses (Written responses from 2 of 5 reviewers)

- Specific Strengths
  - Excellent results and approaches.
  - Good mechanical property and modeling work.
- Specific Weaknesses
  - None noted.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 0 of 5 reviewers)

- None noted by reviewers.

Question and Answer Session at Review

Q: Craig Haberger – Is the filter going to be operated above 750°C? From your presentation, you appear to be looking at temperatures beyond 750°C. Will this be used for a control strategy?
A: Yonushonis – Our approach neither is nor optimized at this point, so we decided to look at the stresses out to 1000°C.

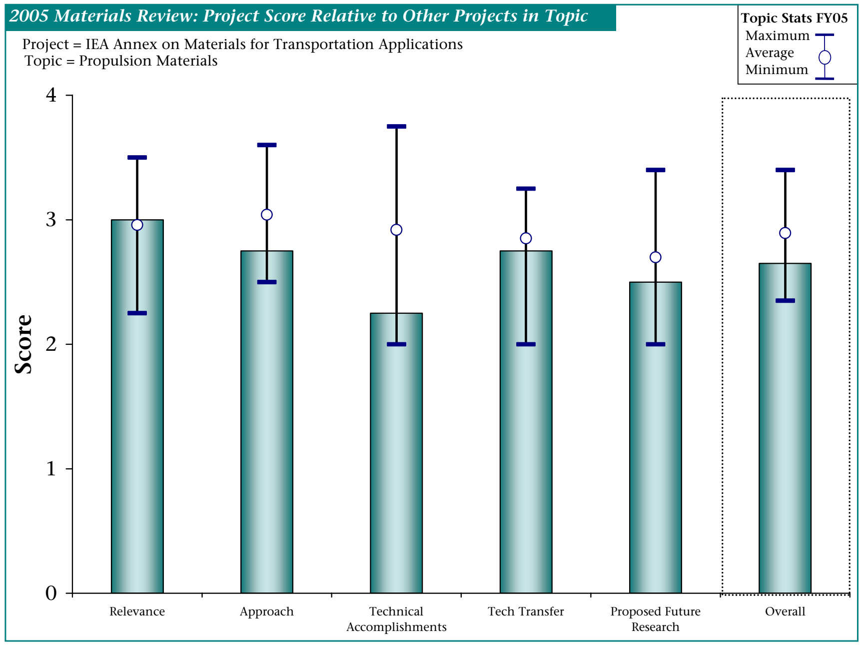
Q: Ed Kraft – The microscopic stresses in the ceramics at 50% porosity are twice the macroscopic stresses. Does this matter in life assessment models or have you made corrections for this?
A: Yonushonis – Final validation will occur during the final burn test, which will confirm our analysis and will determine if the safety factors we used are sufficient or need to be modified.

Q: Rogelio Sullivan – Does the filter container (canning and packaging) affect the filter life?
A: Yonushonis – Some believe that the filter can pressures actually extend the filter life by reducing the stress on the filter. However, as the can structure slowly deteriorates from these stresses, it is unclear whether the stresses in the filter will remain as the can pressure relaxes.

Q: Bob Larsen – You have done work on cordierite; have you done any analysis on other 'new' materials?
A: Yonushonis – We have performed an analysis on silicon carbide materials and other new materials. We need to be ready for anything that may arise.

Heavy Vehicle Propulsion Materials

IEA Annex on Materials for Transportation Applications; Andy Wereszczak and Mattison Ferber of Oak Ridge National Laboratory



Brief Summary of Project

This work is designed to promote commercialization of new materials technologies by developing standard testing and characterization methods in conjunction with national and international standards communities. This year's focus was to complete a preliminary investigation of characterization techniques for assessment of contact damage and quantitative adherence measurements for ceramic coatings for wear and thermal management.

Question 1: Relevance to overall DOE Objectives (Written responses from 4 of 4 reviewers)

One reviewer noted that the project is focused on developing methods for evaluating candidate materials. Another person felt that this is an interesting approach, particularly the laser shot peen for coating delamination and also the C-sphere information. One reviewer noted that project is also working on coating adhesion and rolling contact fatigue; both are important problems to be solved for new materials for engine components. The final reviewer pointed out that the techniques are needed for enabling coatings development in terms of adherence and durability. Rolling contact fatigue also needs to be well understood.

Question 2: Approach to performing the research and development (Written responses from 3 of 4 reviewers)

One reviewer commented that the researchers have used a good approach to evaluate fundamental mechanisms. Even though their goal is to establish a non-specific characterization method, noted this reviewer, it still needs to be eventually correlated to a real-life application. One reviewer pointed out that the results of coating-adherence tests probably are influenced by a number of factors in addition to the strength of the bond. Examples are strain rate, ductility and toughness of the coating, difference between elastic moduli of substrate and coating, etc. The last reviewer questioned the use of commercial laser shot peening equipment to calculate coating strength.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 3 of 4 reviewers)

One reviewer commented that the initial work is interesting and shows promise, but wondered what connection there is to real-life environments and applications. Another reviewer pointed out that no actual bond coating strength calculations were done. The last reviewer commented that significant questions remain about both test techniques.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 3 of 4 reviewers)

One person noted the researcher worked with LSP Technologies, but felt that they still need to find industrial partners. Another agreed, adding that input from industry will be important to identify service conditions under which adhesion or fatigue failures occur. The last reviewer questioned where the technology is heading. The reviewer asked if there is interest from industrial partners besides the LSP or ball-machining suppliers, and suggested that the researchers need guidance from an engine OEM and its component suppliers.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 3 of 4 reviewers)

One reviewer noted that the researchers plan to participate in international organizations to develop standards. Another person felt that it is not clear whether all of the important issues that need to be resolved have been identified. The last reviewer felt that the researcher still needs to identify a commercialization path, even though it may be a hand-off to other programs.

Specific Strengths and Weaknesses (Written responses from 3 of 4 reviewers)

- Specific Strengths
  - Innovative approaches to difficult problems.
  - Fundamental understanding. The LSP is an elegant experimental technique.
  - Interesting approach in conducting laser thermal shock using shot peen laser techniques.
- Specific Weaknesses
  - No actual bond coating strength calculation.
  - Have not considered all of the complicating factors.
  - No end-use is considered other than general hypothetical engine applications.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 3 of 4 reviewers)

- No actual bond coating strength calculation.
- Determine how to calibrate results of coating-adherence tests with damage mechanisms experienced in service.
- At the very least, interview engine and component suppliers to identify critical parameters.

Question and Answer Session at Review

Q: Peter Blau – Does the ball orientation bias the test's ability to detect flaws in certain locations?
A: Werezczak – Yes, it may be difficult to evaluate stress and strain with a ball, however we are hopefully that we will be able to identify flaws through signature analysis and through rotation of the ball.

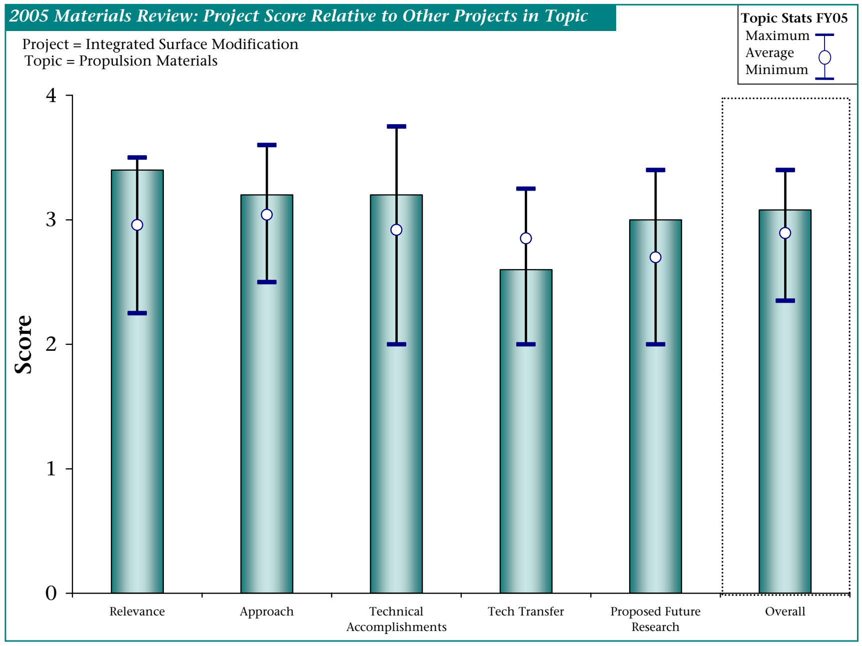
Q: Ray Fessler – In regards to measuring adhesion of coatings, does the strain rate affect the value to be measured?
A: Werezczak – We are unsure at this point, and we haven't gotten to the point of evaluating rate effects. The elastic properties of the material are related to the speed and attenuation of the wave.

Q: Ray Fessler – What about the ductility and toughness of the coating? Does this test address this? It looks to be very difficult.
A: Werezczak – The apparent strength will include all of those material properties, it will depend on data interpretation.

Integrated Surface Modification; Stephen Hsu of NIST

Brief Summary of Project

In this project, the researchers are developing surface texture features and patterns that will control friction and increase durability. They are also developing cost-effective fabrication techniques, developing thin films to enhance/protect the textures, and developing lubricant chemistry to further increase the robustness of the surface technology. They are working with industrial partners to validate the technology, and developing a design guideline (tool chest) for various materials and application conditions.



Question 1: Relevance to overall DOE Objectives (Written responses from 3 of 5 reviewers)

One person noted that the project's goal is to reduce wear to improve engine system efficiency. Another felt that the researchers need to show the relation between parasitic loss reduction and fuel economy (projected benefits) for heavy-duty diesel engines. The final reviewer said that the researchers should link fuel economy with friction reduction.

Question 2: Approach to performing the research and development (Written responses from 4 of 5 reviewers)

One reviewer simply stated that the presentation showed interesting approaches. Another person commented that the researchers have used good fundamental research on determining the influence of size and shape on friction reduction. Another person commented that the approach has been primarily empirical, which probably is appropriate so far, but efforts at modeling should be considered. The last reviewer felt that a commercialization path needs to be integrated into the technical plans.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 4 of 5 reviewers)

Several reviewers had positive comments. One person simply stated that the project has shown interesting results. Another noted that interesting technologies have been demonstrated. A reviewer commented on the great findings with respect to the shape and size of the texture. The last reviewer commented that this appears to be an area that will require a long-term effort and that it would be useful to construct a roadmap showing a timeline to practical results.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 5 of 5 reviewers)

Reactions were mixed to this question. One reviewer felt that there was wide collaboration among partners and international organizations. Others were more skeptical. One person commented that in spite of a slide showing interactions, there was no evidence of such. They also noted that it was clear from the discussion that ANL and ORNL could make valuable contributions to the project; involvement of industry also needs to be accelerated. Another reviewer agreed that it was not clear how much industry involvement was present in the project; however, they are putting together a notice. This was reiterated by another person who was glad to see the efforts to organize a working group. They feel that there is a need to follow up with commitment from the proposed partners to identify an appropriate new product introduction that is aligned with significant milestones. One failing of the project is that the project decision point is obviously too late for the 2007 emissions target, but fits well with the 2010 emissions target. The last reviewer suggested that it is now critical to focus on how to implement this in manufacturing.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 5 of 5 reviewers)

Several reviewers had similar comments that the project should move forward. One person added that the plan needs to be expedited. One reviewer noted that Regime III seems to be the most critical and best situated for benefiting from this technology, so they encourage moving in that direction as rapidly as possible. Another person suggested that the researchers make sure components are selected based on greatest payback for the technological enhancements. The final comment was that working on the high load low speed areas seems to be the correct path.

Specific Strengths and Weaknesses (Written responses from 4 of 5 reviewers)

- Specific Strengths
  - Interesting approach that seems to work.
  - Directed toward understanding a potentially very important approach to reducing friction and wear.
  - Fundamental tribological mechanisms are well-understood. Processing capabilities. Potential partners identified.
  - Very interesting way of reducing friction by texturing.
- Specific Weaknesses
  - Extremely complicated multi-variable problem.
  - Timeline not focused on commercialization path.
  - Commercial path needs to be defined.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 2 of 5 reviewers)

- Concentrate on Regime III rather than I or II.
- Target components need to be identified very soon based on 2010 engine strategies.

Question and Answer Session at Review

Q: Claus Daniel – The effects due to topographic texture changes have been investigated. Have you looked at chemical or mechanical changes?
A: Hsu – We have eliminated those for now, and are moving in a step-by-step process by investigating topographic changes first. We are looking first at topographic effects, then production issues, then lastly chemical effects.

Q: Claus Daniel – What is the size of the dimples?
A: Hsu – They are very small, with 7 % area density. They are 150 microns long, 8 microns deep, with pitch of 500um. The total area of the sample is 15,671 square microns. With light contact pressures, a 15% area density is good, but as loads increase, more texture is actually detrimental.

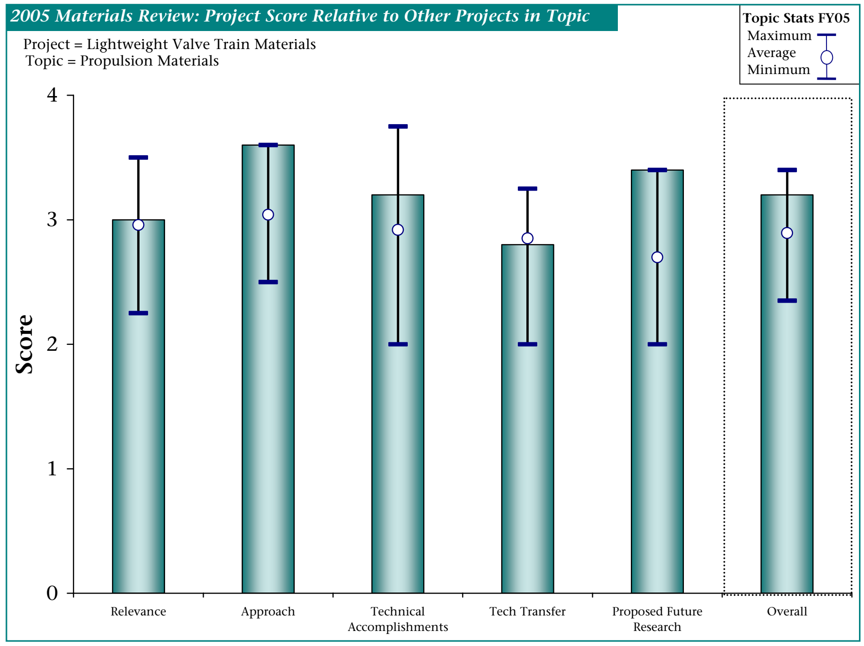
Q: The pitch is shown at 0.5 mm; how does this compare with contact area? We found it important to keep all these dimples placed properly.
A: Hsu – Relative to contact area, there is an optimum ratio for high/low regime, and for the high regime this changes dramatically – area density is referred to the area density inside the contact area.

Q: Dr. James Eberhardt – What about the chemical effects?
A: Hsu – Different materials react to stresses in different ways. Different materials can use different texturing methods.

Q: Rogelio Sullivan – Relative to the next step of industry interaction, what other industries besides the US engine manufacturing could use this concept?
A: Hsu – United Technologies is using this in gears for Otis elevators. Others include marine outboard motor companies, seal and bearing companies, and material supply companies.

Heavy Vehicle Propulsion Materials

Lightweight Valve Train Materials; Jeremy Trethewey of Caterpillar Inc., J.G. Sun of Argonne National Laboratory, and H.T. Lin of Oak Ridge National Laboratory



Brief Summary of Project

This team is working to design, procure and validate heavy duty TiAl and Si_3N_4 valves, as well as to develop life prediction tool to assist in component design with brittle materials. Their FY 2005 focus is on validation of valve performance on a Caterpillar G3406 engine platform at the National Transportation Research Center.

Question 1: Relevance to overall DOE Objectives (Written responses from 2 of 5 reviewers)

One reviewer noted that the project goals are to improve energy efficiency and enhance durability. Another reviewer had detailed comments about the project. They commented that the project needs to quantify the expected advantages of thermal efficiency, to discuss how much the overspeed advantage relates to thermal efficiency goals, and to discuss expected improvements in durability over commercial practices. Weight reduction of the components does not greatly affect fuel economy of the complete vehicle; it is an issue whether the cost of these components can prohibit application in a production engine.

Question 2: Approach to performing the research and development (Written responses from 2 of 5 reviewers)

One reviewer simply stated that the researchers have a very comprehensive evaluation program. Another reviewer agreed, stating that they have used a very good layout of approach and a well defined plan with a good mix of bench testing and engine testing. They also noted that the modeling work is spread throughout the project providing good coverage.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 2 of 5 reviewers)

One reviewer simply noted the good progress in all aspects. Another reviewer commented that the progress is still restricted to "bench studies," modeling, and some fabrication work and that the full application on an engine system has yet to be realized.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 2 of 5 reviewers)

One reviewer highlighted the close collaboration with Oak Ridge National Laboratory and Argonne National Laboratory. Another noted that the collaboration was limited to Caterpillar, national labs, and suppliers, but no names for the suppliers were mentioned.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 2 of 5 reviewers)

One reviewer simply stated that the researchers have a good plan. Another commented that the future does include engine systems testing, and there was also a mention of driving down the cost of fabrication.

Specific Strengths and Weaknesses (Written responses from 3 of 5 reviewers)

- Specific Strengths
  - It is a great integrated program.
  - Sharply focused research program.
  - Good collaborative effort with ORNL and ANL.
- Specific Weaknesses
  - Not clear how this will result in fuel savings.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 1 of 5 reviewers)

- None mentioned by reviewers.

Question and Answer Session at Review

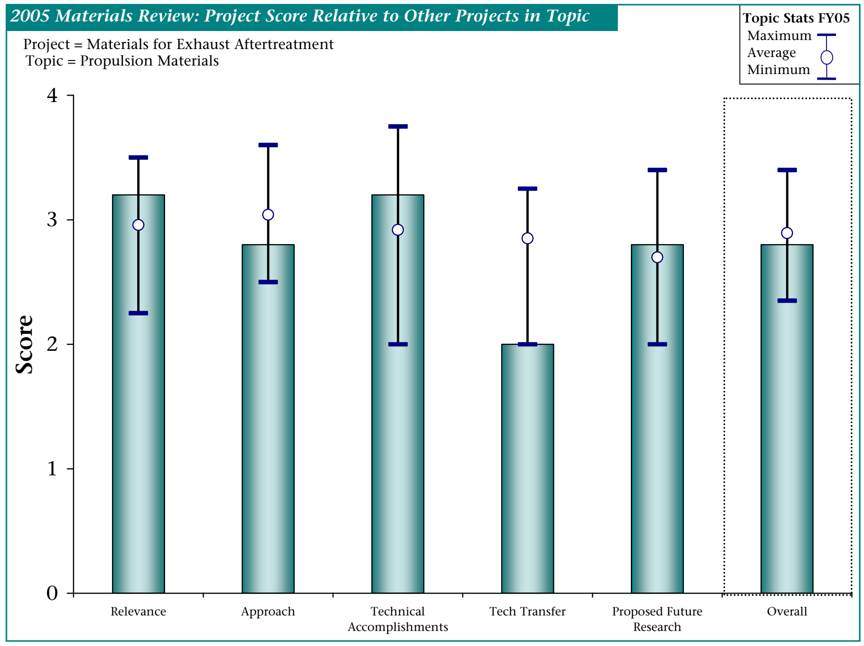
Q: Ed Kraft – Did you look at post machining heat treatment for the silicon nitride valves? This can have a significant effect on lifetime and wear.
A: Trethewey – No, not in this project.

Q: Joe Horton – When can we expect to see camless engines in cars and trucks?
A: Trethewey – Camless should not be too far out. The technology is available, just waiting for the right cards to fall. For hydraulic piezoelectric actuation, the inertia of the valve is a key issue related to actuator size and power requirements; if you can cut the inertia in half, that would probably be significant enough to attain a commercial readiness.

Q: Bob Larsen – This project focuses on exhaust valves, have you looked at intake valves? Is it possible for you to change the design parameters to incorporate intake valves?
A: Trethewey – Actually, a limited number of titanium aluminum intake valves will be produced, and some silicon nitride valves may be produced. Intake valves are relatively similar to exhaust valves, only a small change in code is required to produce the intake valves. We haven't looked at the geometry optimization for intake valves.

Q: Steve Hsu – Interesting choice of natural gas engine, as it has a very clean operation with very different stresses than those that occur in diesel engines. How do you extend this analysis to on-highway diesel engines?
A: Trethewey – We were looking at natural gas engine as the first trial, with conventional engines in a second trial. Before we go further, we will test in an on-highway application.

Q: Dr. James Eberhardt – What kind of production yields are you getting in the production of these ceramic valves to achieve defect-free valves?
A: Haberger: Yields were relatively low (less than 50%), but these are large valves.



Brief Summary of Project

This project is working on materials research and development that will be applied in advanced diesel engine aftertreatment systems to comply with future emission regulations with minimum fuel penalty. The current focus is on evaluating new materials for particulate matter filtration efficiency and back pressure, as well as assessing the impact of phosphorus on oxidation, NOx adsorber (lean-NOx traps) and urea selective catalytic reduction catalysts.

Question 1: Relevance to overall DOE Objectives (Written responses from 4 of 5 reviewers)

One reviewer commented that the project is geared to the emissions goal of DOE. Aftertreatment durability issues are also part of meeting EPA requirements in 2010. Another simply stated that the project is focused on improving fuel efficiency and reducing emissions. Another reviewer noted that the researchers demonstrated the influence of improved catalyst performance on fuel economy for diesel engines. The final reviewer had detailed comments; the reviewer commented that this project is a very good effort aimed at understanding the impact of oil formulation on catalyzed diesel particulate filters, lean NOx traps, and urea selective catalytic reduction systems. Such aftertreatment does not directly address the 21CTP goal of augmenting vehicle fuel economy, but must be addressed since it a necessary ingredient in meeting 2010 emission standards. Furthermore, such work points toward additional effort necessary to ensure integration of aftertreatment systems into future heavy-duty vehicles.

Question 2: Approach to performing the research and development (Written responses from 2 of 5 reviewers)

One reviewer noted that the researchers used the basic approach of using a diesel fired burner rig. Another reviewer commented that phosphorous poisoning was being done at an engine testing level by Oak Ridge's NTRC, and they suggested that this project should also be elevated to an engine testing level.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 2 of 5 reviewers)

One reviewer noted that the progress towards project goals is good. Another reviewer commented that much insight has been generated into how phosphorus impacts NOx aftertreatment devices and these surprising results point toward additional required effort by the engine and energy community for ensuring successful integration of such devices into future trucks.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 4 of 5 reviewers)

One reviewer noted that the researchers worked with catalyst suppliers. Two other reviewers commented that the project is industry specific to Caterpillar, so the technology transfer is limited to Caterpillar and Caterpillar suppliers. The final reviewer felt that it was unclear whether Caterpillar is working with industry and universities.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 2 of 5 reviewers)

One reviewer suggested that future work should include engine level testing, even though engine level testing is not applicable to all areas of the project. They added that material poisoning done in this project may well be better characterized in engine tests. Another reviewer commented that effort for the next fiscal year should reveal insight into the combination of fuel and lubricant effects on aftertreatment devices, i.e. phosphorus and sulfur contributions.

Specific Strengths and Weaknesses (Written responses from 1 of 5 reviewers)

- Specific Strengths
  - This project has the right type of lead company who manufactures engines and develops much of their product subsystems to perform the aforementioned lube oil/aftertreatment contamination effect study.
- Specific Weaknesses
  - Is limited to one engine company.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 0 of 5 reviewers)

- None noted by reviewers.

Question and Answer Session at Review

Q: Ron Graves – How was the phosphorous introduced to the engine in the test? As ZDDP?
A: DaCosta – Phosphorous added as another form, not through ZDDP. Therefore, there was no zinc poisoning. This simulated oil getting into the exhaust through the combustion chamber and combustion of lube oil.

Q: Rogelio Sullivan – In regards to the diesel particulate filter, you have looked at filtration efficiency and backpressures. How does this material get regenerated? Is it exposed to thermal shock? Is this part of the test plan?
A: DaCosta – Next year we will focus on thermal deactivation of the materials. We are also using different procedures to achieve thermal aging.

Q: What was the layout of the test monoliths relative to cordierite filters?
A: DaCosta – Same macro-level geometric features, with 200 cells per square inch, 70 open channels for filter access.
A: Silver – 400 cells per square inch were used in the NOx work.

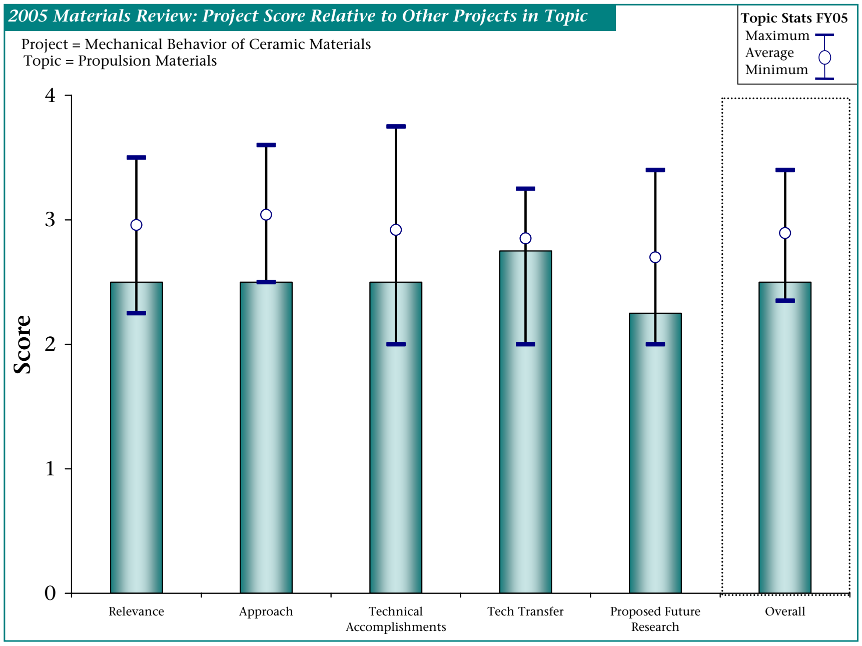
Q: Bob Larsen – With these oil-borne contaminants present presumably as part of necessary lubricating packages, what is the feasibility for tightening up the engine to reduce oil consumption as a possible mitigating approach to reduce the impact of phosphorous on the NOx aftertreatment?
A: DaCosta – 800 ppm is the new target for new oils for phosphorous content for 2007. Several different approaches can be used to achieve the reduction of phosphorous poisoning in the exhaust stream. One approach is to reduce the phosphorous in the engine lube oil. A second approach is to tighten the engines to zero oil consumption, but this isn't likely as engines will always burn some oil. Oil companies tried oil formulations without phosphorus, but lubricity went nearly to zero and significant problems arose. Calcium may be another lubricity additive to consider when reducing/eliminating phosphorous without losing the lubricity of the engine lube oil.

Heavy Vehicle Propulsion Materials

Mechanical Behavior of Ceramic Materials; Andy Wereszczak of Oak Ridge National Laboratory

Brief Summary of Project

This team is looking to enable the development of more wear-resistant and mechanically robust ceramic components through the systematic evaluation of contact damage in ceramics. Their FY 2005 focus is to evaluate rate and grain size effects on contact damage in candidate ceramics for diesel engine components, and to develop a criterion to rank/compare damage resistance.



Question 1: Relevance to overall DOE Objectives (Written responses from 2 of 4 reviewers)

One reviewer noted that the project goal is to increase fuel efficiency. Another reviewer wondered if there really is a significant payback for the rolling elements identified. They concluded, stating that they were not sure how the piezostack fuel injector improves engine efficiency.

Question 2: Approach to performing the research and development (Written responses from 2 of 4 reviewers)

One reviewer noted that the approach is to characterize damage processes through static and dynamic indentation. Another reviewer commented that the correlation of fundamental characteristics to design parameters is not demonstrated.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 2 of 4 reviewers)

One reviewer noted that the accomplishments include the development of micro-FEA software and studying static vs. dynamic responses in Si_3N_4. The other reviewer commented that the techniques show promise in improving ceramic machining parameters and coating design, as well as reliability.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 2 of 4 reviewers)

One reviewer felt that there was a good connection to Delphi and Cerbec. Another person noted the reviewers have copyrighted the micro-FEA program.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 1 of 4 reviewers)

One reviewer felt that the goals and benefits for piezostack development need to be more clearly identified.

Specific Strengths and Weaknesses (Written responses from 1 of 4 reviewers)

- Specific Strengths
  – Collaboration and fundamental understanding.
- Specific Weaknesses
  – Unclear goals, benefits, and time targets.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 0 of 4 reviewers)

- None mentioned by reviewers of this project.

Question and Answer Session at Review

Q: Rogelio Sullivan – With your current work ending soon, in regards to the new piezoelectric materials work for fuel cells with Delphi, will you be able to use some of the tools developed during this project?

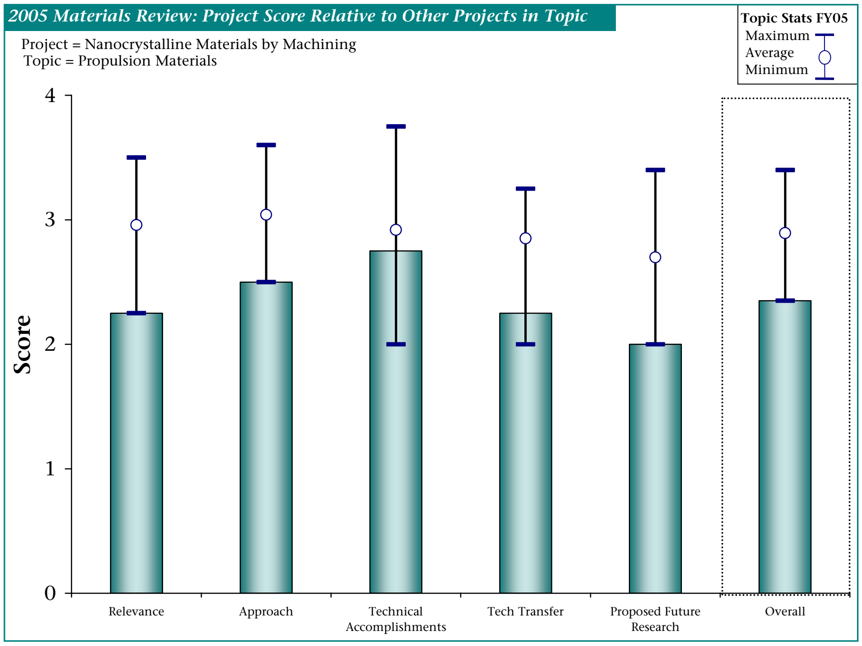
A: Werezczak – Yes, many of the same processes developed during the project can be used for the work with Delphi to test the high rate mechanical performance of the piezo materials.

Heavy Vehicle Propulsion Materials

Nanocrystalline Materials by Machining; Srinivasen Chandresekar of Purdue University

Brief Summary of Project

This project is working to develop ultra-fine grained alloys from machining chip particulate via advanced powder processing. The 2005 focus is on TEM studies of nanostructure development in machining, and low-temperature consolidation routes for Al 6061-T6.



Question 1: Relevance to overall DOE Objectives (Written responses from 2 of 4 reviewers)

One person noted that the project is working on low-cost processing for nanomaterials. Another reviewer felt that the relevance of the project's end goal to efficiency benefits is not specifically defined, and wondered what the economic characteristics of this technique are.

Question 2: Approach to performing the research and development (Written responses from 2 of 4 reviewers)

One reviewer noted that the approach is to produce powder form and bulk samples. Another reviewer commented that the property improvement targets should be clearly laid out with relevance to the 21CTP goals. They also asked whether the high-strain rate method can be achieved by other methods outside of chip machining.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 2 of 4 reviewers)

One reviewer noted that the researchers have produced a wide variety of forms of nano chips and bulk material. Another reviewer commented that this is a very interesting technique with a method has been demonstrated on a broad range of materials. They added that the studies on chips are interesting, but the practical application is not evident. They suggested that extrusion cutting may show more promise for niche applications.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 2 of 4 reviewers)

One reviewer noted that the researchers have worked closely with many suppliers and end users. Another person commented that the technique seems to have broad applications in terms of bulk component processing and component designs. They asked about the main cost drivers and/or benefits that are being investigated, and asked what the researchers intend for these chips: will they be a primary source of material, or additions to composites?

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 2 of 4 reviewers)

One reviewer felt that the researchers have laid out a good plan. The other reviewer commented that this appears to be very process-intensive; a cost study is necessary. They felt that the overall objective for bulk prototypes is vague.

Specific Strengths and Weaknesses (Written responses from 2 of 4 reviewers)

- Specific Strengths
  - Novel technique to obtain interesting material properties.
  - Innovative technique and thought.
- Specific Weaknesses

- Cost and commercial applications are not defined.
- Seems fragmented with no real applications targeted, at least it was not clear in the presentation.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 2 of 4 reviewers)

- Fully evaluate the material properties of parts made from the machined chips.
- Partner with an OEM engine and component supplier to define interest.

Question and Answer Session at Review

Q: Claus Daniel – The principal mechanism of this effect is deformation, what are the advantages and disadvantages of this technique relative to other techniques?
A: Chandrasekar – Nanocrystalline materials can be made through equal channel angular extrusion, but this can be done only on alloys of soft to moderate strength, and the issue of die breakage comes up frequently. The equal channel angular extrusion can make larger samples than the machining chip method.

Q: Paul Becker – Does the material retain its nanostructure as it ages? Does it resist overaging?
A: The material does retain its structure as it ages, but it is not clear whether it resists overaging.

Q: Jean-Louis Staudenmann – What is the cost of this process?
A: The machining to make the particles can cost $1-3 per pound depending on material.

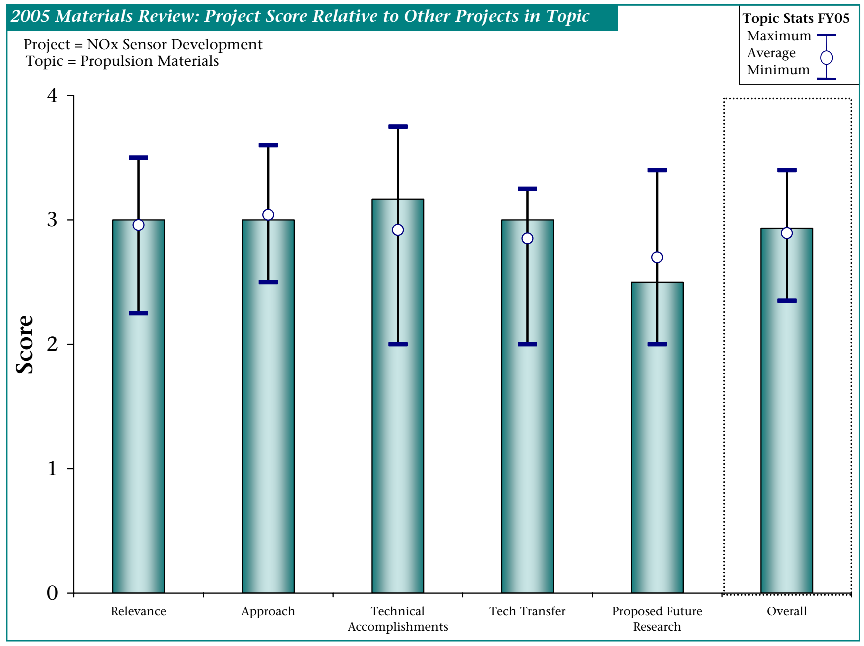
Q: Phil Sklad - It may be better and more cost effective to use scrap chips.

Q: Rogelio Sullivan – Do the chips have to be clean?
A: Yes.

Q: Jean-Louis Staudenmann – What is the effect of the process on tooling?
A: We have seen no tool wear for aluminum alloys: we do not have data for other materials.

Q: Paul Becker – This process could provide benefits for all but hardened steel. No one is making machined hardened steel, so other processes would still have to be done to produce sufficiently hardened material.

NOx Sensor Development; Tim Armstrong of Oak Ridge National Laboratory



Brief Summary of Project

In this project, the team is developing NOx sensors suitable for OBD (remediation and/or monitoring) of diesel engine exhausts. In 2005, they focused on stability of electrode materials and cross-sensitivity of the sensors to other gases.

Question 1: Relevance to overall DOE Objectives (Written responses from 3 of 6 reviewers)

Two reviewers noted that the project's goal was to develop a sensor for emission control for engine OEMs, which is an identified need. One reviewer added that this may be too late for 2010, since it must be commercialized by 2008 with evaluation hardware available in 2006. The last reviewer commented that this project indirectly addresses 21CTP goals by enabling the use of NOx aftertreatment that requires active monitoring of exhaust gas NOx concentration. They added that such a sensor will be important for both meeting emission standards and also for reducing associated fuel consumption penalties associated with reducing NOx.

Question 2: Approach to performing the research and development (Written responses from 3 of 6 reviewers)

One reviewer commented that this was a well thought out experimental effort. Another reviewer felt that the presentation showed a good fundamental understanding of the reactions and sensor interactions; however, without a HD diesel OEM, it is difficult to evaluate the real-life technical requirements. The last reviewer felt that biasing the electrodes is a good idea. The reviewer added that the concept of converting all the NOx to either NO or NO_2 has already been patented and suggested checking the patent literature.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 1 of 6 reviewers)

One reviewer commented that this effort has produced much insight into how to design, fabricate, and integrate a NOx sensor into future NOx aftertreatment systems.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 4 of 6 reviewers)

Reactions to this question were mixed. One reviewer noted the work with Ford, while another felt that there was very good teamwork between industry and the national labs. Another person felt there needs to be more direct collaboration with a diesel engine manufacturer, which appears currently to be only in discussion phases. The final reviewer commented that a sensor manufacturer must be brought in soon to be ready to commercialize.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 2 of 6 reviewers)

One reviewer commented that this was a well thought out project that will continue to focus on packaging, cost, and sensor biasing issues. Another reviewer commented that the researchers need to identify specific engine testing plans.

Specific Strengths and Weaknesses (Written responses from 5 of 6 reviewers)

- Specific Strengths
  - Sensor is critical to the success of the emission control.
  - Fundamental understanding of sensing mechanisms.
  - Good electrochemical focus.
  - Excellent team effort.
  - Good cross functionality with different [gases]. Excellent work and one of the better presentations at the conference. Sensors will become critical for future diesel engines.
- Specific Weaknesses
  - Direct engine OEM involvement is missing up front.
  - The focus on the NOx range is still a little too high at 10ppm. It needs to be ~5 ppm +/-2 ppm for current 2010 not-to-exceed standards of 1.5 (cannot exceed~45 ppm over a 13-mode cycle)
  - None that are obvious.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 2 of 6 reviewers)

- Direct engine OEM involvement is missing up front.
- Look at temperature sensitivity. Ammonia sensitivity. If a commercialization plan for the project is not clearly defined by the end of 2006 I feel there will not be enough time to bring to market for 2010 OBD requirements and the program should be stopped.

Question and Answer Session at Review

Q: Tom Yonushonis – Have you looked at cross-sensitivity of the sensor with ammonia?
A: Armstrong – Yes, ammonia is an issue with any NOx sensor, but we will have a catalyst to convert ammonia to NO and NO_2. Ford is also working on an ammonia sensor.

Q: Tom Yonushonis – What is the target life of the NOx sensor? What is the target lifetime of the oxygen sensor?
A: Armstrong – This is a lifetime sensor to last 1 million plus miles. The oxygen sensor has already been developed (UEGO) but hasn't been commercialized to any degree. The oxygen sensor will also be a one million mile plus lifetime.

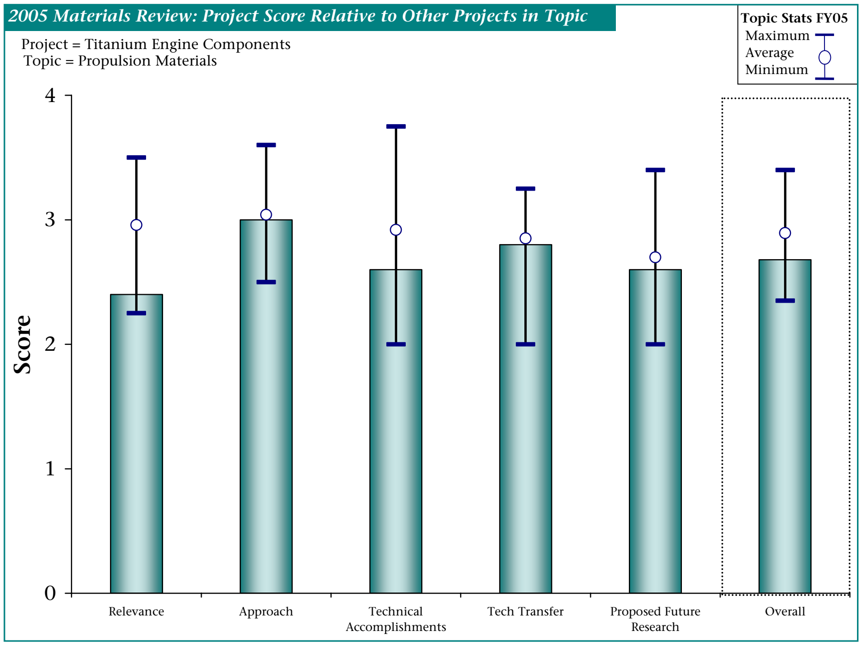
Q: Rogelio Sullivan – What about the electronics required for these sensors? Are you working on the packaging of the required electronics to support the sensor?
A: Armstrong – Ford is working on this system. If they can use a millivolt based sensor, which they believe they can, off the shelf electronics will be used and can be placed anywhere. If a micro-volt sensor is used, the electronics must be placed next to the signal source (sensor) which will significantly increase the cost and complexity of the electronics. Ford is confident they can develop a millivolt sensor and does not believe they will have to do anything special in regards to electronics development.

Q: Craig Haberger – What is the temperature range for the sensor?
A: Armstrong – We are targeting operation between 550°C -700°C, and we expected that we will be able to go to 1000°C. Since we are using biasing – electro-catalytic sensor, these very high operational temperatures are attainable (mixed potential sensors do not work well above 550°C.)

Titanium Engine Components; Paul Becker of the University of Tennessee

Brief Summary of Project

This project had several activities. They included: 1. Using FEA, predict operating temperatures and stresses of a Cummins ISB diesel engine with a titanium cylinder head and block (with cast iron liners) rated at 305 hp and compare to the production grey cast iron. 2. Determine the technical feasibility of using titanium for engine cylinder heads and blocks from temperature, stress and fatigue predictions. 3. Predict operating temperatures and stresses of the engine with a titanium cylinder block and cylinder head, (with inserts in the flame face of each cylinder). Determine feasibility of simultaneously increasing the rating of the engine from 305 hp to 450 hp. 4. Investigate aluminum and magnesium as cylinder block and head materials and compare to cast iron.



Question 1: Relevance to overall DOE Objectives (Written responses from 3 of 5 reviewers)

One reviewer commented that this project has a significant weight saving potential. Another person added that the advantages of lightweighting are obvious, but they need to be quantified with a prediction on fuel savings. The final reviewer had detailed comments, stating that this project is important for exploring the limits in design of heavy-duty engine blocks and heads with light weight materials, but is unlikely to make major progress in improving vehicle fuel consumption due to practical engineering/cost limitations. They add that for example, titanium provides a technical alternative to cast iron blocks for specialty high output applications, but at double the cost which would be difficult to justify for commercial tractor trailer applications.

Question 2: Approach to performing the research and development (Written responses from 3 of 5 reviewers)

One reviewer pointed out that the reviewers used finite element analysis for the feasibility study. Another person felt that this was a well thought out approach for assessing the feasibility of using titanium, aluminum, and magnesium for engine block and heat applications using finite element analysis under the worst case engine duty cycle. The last reviewer commented that the model is generic for the wet-liner engine configuration, which is more common in heavy-duty on-highway applications. Using existing engine models and input from Ricardo made the approach independent from a specific OEM.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 3 of 5 reviewers)

One reviewer commented that this project had interesting findings and demonstrated feasibility in using titanium, aluminum, and magnesium. Another person commented that this is a feasibility study and as noted in evaluation question 1 (relevance) is unlikely to make significant progress is improving vehicle fuel consumption; otherwise, the provided analysis is very valuable for establishing limits for use of the aforementioned light weight materials in heavy-duty engines. The final reviewer commented that the analysis showed potential issues (cylinder head temperatures), along with potential solutions to these barriers. Beryllium-copper alloys may not be practical, but it is a good demonstration of design capabilities.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 3 of 5 reviewers)

One reviewer noted that the researchers worked with Ricardo in its finite element analysis and that Cummins is supplying solid model and boundary conditions. Another person commented that the principal investigator has taken great effort and time to visit various engine manufacturers and potential interested parties to provide an overview of the pluses/minuses of light weight materials. The last reviewer suggested that finding an engine OEM with a specific application in mind would drive this beyond the modeling stage to define real-world requirements and potential validation paths to commercialize.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 3 of 5 reviewers)

One reviewer simply stated that the project needs industrial partners. Another person agreed, stating that the researchers need to identify the partners they have considered to manufacture and test prototype engines; the researchers may have to focus on a specific niche application (most likely military as was pointed out in the discussion). The final reviewer felt that one weakness with any finite element analysis is the lack of material property behavior at various thermodynamic conditions - the future work will address this issue by experimentally determining such properties.

Specific Strengths and Weaknesses (Written responses from 4 of 5 reviewers)

- Specific Strengths
  - Interesting project.
  - Generic modeling capability.
  - The principal investigator has extensive practical engine manufacturer experience that is a very important ingredient for this effort.
  - Great work in modeling.
- Specific Weaknesses
  - Need to model stiffness and redesign geometry.
  - Lack of industry commitment. Many technical hurdles to overcome.
  - Cost (machining)/material costs and customer pull will be two major issues.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 2 of 5 reviewers)

- Cost benefit analysis with titanium, aluminum, and magnesium compared to cast iron.
- Demonstrate the real-world benefits in business case to win over the right industrial partners.

Question and Answer Session at Review

Q: Mark Horstmeyer – Even in a feasibility study like this, I believe it is important to look at material stiffness as well. Optimization of geometry is important to address the differences in material stiffness.
A: Becker – I agree this would be the next step after this feasibility study.

Q: Claus Daniel – In regards to your analysis of using titanium as a replacement material, have you looked at the problem with thermal expansion of the inserts?
A: Becker – I have these data but did not discuss due to time constraints. Stresses in the inserts will be developed at the interface due to thermal mismatches, but can be addressed with design changes (which is part of Ricardo's design experience). These inserts must be bonded on their back face to provide a seal and to have contact with coolant, but can be left loose in the radial direction for expansion.

Q: Claus Daniel – Have you considered the environmental implication of using beryllium?
A: Becker – We are not wedded to the beryllium-copper alloy but liked the material properties very much. For the next step, more analysis would be needed to determine the specific material needed to achieve the specified performance. Beryllium-copper alloys are used in many industries and since this alloy is only composed of 2% beryllium, toxicity is not an issue when it is mixed at this ratio with copper.

Q: James Quinn – Is the cost premium of using these lightweight materials being investigated?

A: Becker – We didn't do a rigorous cost analysis. The cost estimate is based upon experience. To replace the engine block and head with the lightweight material, the cost premium, as compared to cast-iron (including machining/manufacturing costs) would be:

- Using titanium would increase engine cost by 100%
- Using aluminum would increase engine cost by 0% (manufacturing and machining offset material costs)
- Using magnesium would increase engine cost by several % (head and block 20% more)

DOD is focused on weight and size savings more than cost, and this could be an initial arena.

Q: James Quinn – Are you aware of work being done in automotive arena on magnesium engine development?
A: Becker – Yes, I am aware of this work; however, as I stated in my presentation what's good for automotive applications is not necessarily good for heavy duty diesel applications. Cylinder pressures are quite different between the two engine types. Experience on issues like galvanic corrosion of dissimilar materials could transfer. Alloys for heavy-duty applications are not like those for light-duty; higher performance is needed.

Q: Rogelio Sullivan – Using lightweight materials as engine block and head material replacements are stretch ideas in the trucking industry, how was your presentation received at Caterpillar and Cummins?
A: Becker – It was hard to read them. I do not believe that titanium excited them, although aluminum had some attraction to them, since it is a known entity with good benefits. However, aluminum does not have the maximum weight and strength benefits of the other lightweight materials. I was not sure what these two engine builders thought of magnesium.

Q: Harold Johnson – Does the fuel efficiency of the engine improve by using the materials you discussed?
A: Becker – It depends on tying fuel economy to thermal management. If you tie fuel economy to the weight reduction of the engine, you would get fuel economy benefits from using the lightweight material but I am not sure about the combustion aspect. With some of the material advancements discussed by Peter Blau, there may be opportunities. Titanium has one-quarter the thermal conductivity of iron: it could be used as a cylinder liner to hold heat in the cylinder, and the titanium oxide film could be used for wear resistance.

HEAVY VEHICLE MATERIALS MERIT REVIEW AND PEER EVALUATION

Evaluation Form **September 2005**

PROJECT NUMBER: ______________________________

PROJECT TITLE: ______________________________

PRESENTER: ______________________________

REVIEWER NAME: ______________________________

Using the following criteria, please rate the **work** presented in the context of the program objectives. Please provide **specific** comments to support your evaluation.

1. Relevance to overall DOE objectives (degree to which this project supports the goals and objectives of the 21 CT Program and DOE Multi-Year RD&D Plans).

Numeric rating (circle one below)
4 = Outstanding, the project is sharply focused on one or more key technical barriers in materials R&D.
3 = Good, most aspects of the project will contribute to significant progress in overcoming these barriers.
2 = Fair, some aspects of the project may lead to progress in overcoming some barriers.
1 = Poor, the project is very unlikely to make significant contributions to overcoming the barriers.

Specific comments

2. Approach to performing the research and development (degree to which technical barriers are addressed: quality of project design, technical feasibility, and integration of project with other research).

Numeric rating (circle one below)
4 = Outstanding, it is difficult for the approach to be improved significantly.
3 = Good, the approach is generally well thought out and effective, but could be improved in a few areas.
2 = Fair, the approach has significant weaknesses.
1 = Poor, the approach is not responsive to the project objectives.

Specific comments

3. Technical Accomplishments and Progress toward project and DOE goals (degree to which progress is gauged against performance measures, and degree to which the activities improve the state-of-the-art in performance relative to DOE program goals).

Numeric rating (circle one below)
4 = Outstanding, the project has made excellent progress toward overcoming one or more key DOE program technical barriers; progress to date suggests that the barrier(s) will be overcome.
3 = Good, the project has shown significant progress toward overcoming barriers.
2 = Fair, the project has shown a modest amount of progress in overcoming barriers, and the overall rate of progress has been slow.
1 = Poor, the project has demonstrated little or no progress toward overcoming the barriers.

Specific comments

4. Technology Transfer/Collaborations with industry, universities, and other laboratories (how well do the project team members relate with other institutions and projects).

Numeric rating (circle one below)
4 = Outstanding, close coordination with other institutions is in place; industrial partners are full participants.
3 = Good, some coordination exists; full coordination could be accomplished fairly quickly.
2 = Fair, some coordination exists; full coordination would take significant time and effort to initiate.
1 = Poor, most or all of the work is done at the Lab with little outside interaction.

Specific comments

5. Approach to and Relevance of Proposed Future Research (how well will the future research plan achieve the goals set forth for the project and for the DOE programs in general).

Numeric rating (circle one below)
4 = Outstanding, future work plan builds on past progress and is sharply focused on one or more key DOE program technical barriers.
3 = Good, future work plan builds on past progress and generally addresses removing or diminishing barriers in a reasonable timeframe.
2 = Fair, future work plan may lead to improvements, but should be better focused on removing or diminishing key barriers within a reasonable time period.
1 = Poor, future work plan has little relevance or benefit toward eliminating barriers.

Specific comments

6. Specific Strengths of This Research

7. Specific Weaknesses of This Research

8. Specific Recommendations or Additions/Deletions to Work Scope

Acronym	*Definition*
21CTP	21st Century Truck Partnership
ACEM	Aberration-corrected electron microscope
APTA	American Public Transportation Association
BSFC	Brake specific fuel consumption
CAE	Computer aided engineering
CRADA	Cooperative Research and Development Agreement
DOE	Department of Energy
DOT	Department of Transportation
EGR	Exhaust Gas Recirculation
EPA	Environmental Protection Agency
FEA	Finite element analysis
FSJ	Friction Stir Joining
FSW	Friction Stir Welding
FY	Fiscal Year
GREET	Greenhouse gases, Regulated Emissions, and Energy use in Transportation
HD	Heavy-duty
HSWR	High Strength Weight Reduction
HV	Heavy vehicles
HVPM	Heavy Vehicle Propulsion Materials
IEA	International Energy Agency
LSP	Laser shot peening
MMC	Metal Matrix Composite
NIST	National Institute for Standards and Technology
Nox	Oxides of nitrogen
NTRC	National Transportation Research Center
OBD	On-board diagnostics
OEM	Original Equipment Manufacturer
ORNL	Oak Ridge National Laboratory
PNNL	Pacific Northwest National Laboratory
R&D	Research and development
RTM	Resin transfer molding
SMC	Sheet molding compound
SPF	Superplastic Forming
TACOM	US Army Tank-Automotive and Armaments Command
TEM	Transmission Electron Microscope
ZDDP	Zinc dialkyldithiophosphate

A Strong Energy Portfolio for a Strong America
Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. By investing in technology breakthroughs today, our nation can look forward to a more resilient economy and secure future.

Far-reaching technology changes will be essential to America's energy future. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a portfolio of energy technologies that will:

- Conserve energy in the residential, commercial, industrial, government, and transportation sectors
- Increase and diversify energy supply, with a focus on renewable domestic sources
- Upgrade our national energy infrastructure
- Facilitate the emergence of hydrogen technologies as vital new "energy carriers."

The Opportunities
Biomass Program
Using domestic, plant-derived resources to meet our fuel, power, and chemical needs

Building Technologies Program
Homes, schools, and businesses that use less energy, cost less to operate, and ultimately, generate as much power as they use

Distributed Energy & Electric Reliability Program
A more reliable energy infrastructure and reduced need for new power plants

Federal Energy Management Program
Leading by example, saving energy and taxpayer dollars in federal facilities

FreedomCAR & Vehicle Technologies Program
Less dependence on foreign oil, and eventual transition to an emissions-free, petroleum-free vehicle

Geothermal Technologies Program
Tapping the Earth's energy to meet our heat and power needs

Hydrogen, Fuel Cells & Infrastructure Technologies Program
Paving the way toward a hydrogen economy and net-zero carbon energy future

Industrial Technologies Program
Boosting the productivity and competitiveness of U.S. industry through improvements in energy and environmental performance

Solar Energy Technology Program
Utilizing the sun's natural energy to generate electricity and provide water and space heating

Weatherization & Intergovernmental Program
Accelerating the use of today's best energy-efficient and renewable technologies in homes, communities, and businesses

Wind & Hydropower Technologies Program
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